European Three-Phase Railway Systems

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DEVOTED TO THE CONVERSION, TRANSMISSION AND DISTRIBUTION OF ENERGY.

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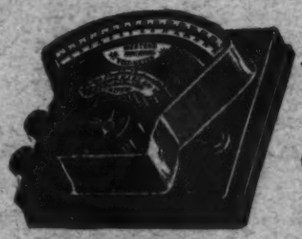

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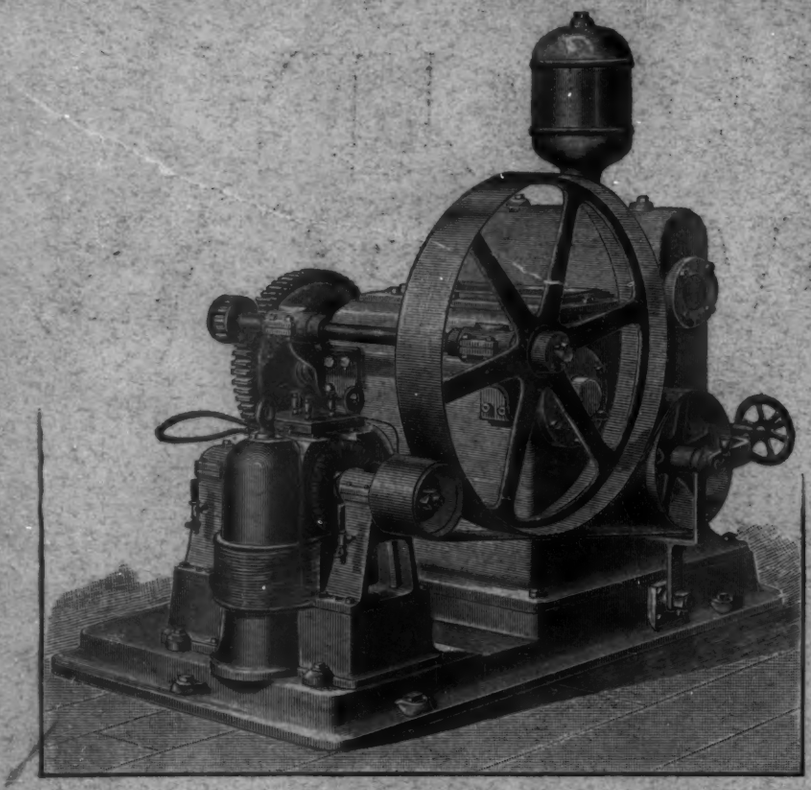

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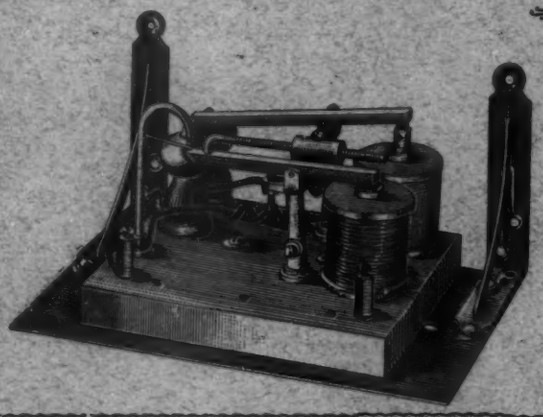

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Devoted to the Conversion, Transmission and Distribution of Energy.

VOLUME XI. SAN FRANCISCO, MARCH, 1901. NUMBER 3.

European Three-Phase Railway Systems.

BY WILLIAM J. HAMMER.

[The great West is as familiarly known as being a country of magnificent distances as it is by any other characteristic. If electric railways are to supplant steam on the standard trunk railroad lines it must do it through the medium of high tension transmission—not only from the generating station to the market, but even to the car itself. To do this best, polyphase currents must be used, as has been repeatedly pointed out in these columns heretofore.

Europe, and especially Switzerland and Italy, leads the world in the application of polyphase current to electric traction. Although it has been known for many months that the three-phase roads here described were under construction, definite details concerning them have not heretofore been available, but now Mr. Hammer has given the much sought for information in a paper presented to the American Institute of Electrical Engineers on February 28th, 1901. The paper discusses many other important European electrical and mechanical engineering developments, and even that portion of it which is now presented above is given in the abstract.—The Editor.]

THROUGH the courtesy of Director Otto F. Blathy, of Ganz & Company, of Buda-Pest, I was enabled to examine into the company's high-tension three-phase railway system, which is now being installed upon the Lecco, Sondrio & Chiavenna line in North Italy, and which system was at the time of my visit being run experimentally upon a circular track a mile in length at Alte-Ofen Island, near Buda-Pest, Hungary. The length of the Italian electric road, which, up to the present, has been operated by steam, is 66 miles and the maximum grade 22 per cent. It is safe to say that this road, by reason of its great length, problems in freight and passenger haulage, high potential employed and its special electrical and mechanical features, represents the most interesting electrical railway instal'ation now under construction, and it will be followed with the greatest interest. The motive power now being arranged for represents about 7400 horsepower, with facilities for increasing when necessary. The power will be derived from a waterfall near Morbegno, 9½ miles from Calico and 15½ miles from Sondrio. Four 2000-horse-power Shuckert three-phase dynamos generating 20,000 volts at 15 cycles are direct-connected to four turbines, which are supplied from a raceway between 2 miles and 3 miles long, delivering 35 cubic meters of water per second, and having a fall of 30 meters. The three-phase current of 20,000 volts will be supplied direct to the line, and the twelve sub-stations will transform it to 3000 vo'ts and supply twelve independent sections of the railway line, each of which is equipped with fuses. Two overhead trolley wires 8mm in diameter represent two of the phases, and the track the third. The line insulators are of porcelain, having five petticoats decreasing in size from top to bottom. The line wire, which is of copper, is 7 mm in diameter. The sections of road are operated upon an ingenious block system; when the stop-signal is set, the line circuit is opened and simultaneously the powerful brakes on the train are set. Passenger and freight traffic are operated independently. The freight locomotives will be of 700 horse power, employin 4 motors, and capable of hauling 250 tons at a speed of 19 miles an hour up a 10 per cent grade. The passenger locomotives are also equipped with four motors representing 300 horse power. The schedule speed is about 37½ miles an hour on the level and about ha'f that on grades. The 3000-volt current is taken from the trolley lines by two a'uminum rollers having a diameter of 3 inches; a collecting brush running on a graphite collar takes the current from the two rollers, which is then led by highly insulated wires, protected by "grounded" metallic tubing. to the motors. Each car is mounted on two four-wheel trucks, and is equipped with two "primary" and two "secondary" induction motors, or four in all, each of 150 horsepower. The 3000-volt current passes directly to the stationary windings of the "primary" motors. In starting up the train or in climbing a grade the motors are connected in "cascade"—that is, the windings of the "primary" rotors, which are designed for 300 volts are connected to the stationary windings of the "secondary" motors, while the rotors are connected to the fluid resistances; this gives a speed of about 18½ miles per hour. When speed is attained the controller is thrown to its second point, which throws the stationary fields of the "primary" motors on the line, and their rotors on the fluid resistances, which are slowly cut out of circuit, the secondary motors, meantime, being thrown out of circuit. This arrangement gives a speed of 37½ miles per hour. The wires in both field and rotor windings are invisible as they pass longitudinally through insulated tubes in the iron, and at the ends of the windings are insulated by mica and protected

THE GANZ THREE-PHASE SYSTEM.

by plates or caps bolted on. The controllers at each end of the car are connected mechanically and the high-tension switches are connected electrically. A small transformer on the locomotive connected to the line delivers current at 100 volts to a three-phase motor for compressing air for use on the air-brakes operating the high-tension switch, raising and lowering the fluid in the resistance boxes (which is simpler than raising the plates), and for raising and lowering the trolley. The same transformer supplies current for lighting the train, Cruto three-phase incandescent lamps being employed. The periodicity being but 15 per second, the fluctuations were too noticeable in the ordinary lamps, so the Cruto three-filament lamp was employed and showed no fluctuations.

The three-phase liquid rheostat is a feature of considerable interest. It consists of an iron box having three wings to it, from the top of which depend three separate cylinders. Supported inside of each cylinder are four iron plates, making twelve in all. They are of varying lengths, and are rounded at the lower extremity. The alternate plates are connected in pairs, the current ent ring at one pair and going out at the other, and are attached to the three phases of the low-tension rotor circuits, which have a potential of 300 volts. The lower portion of the outer case contains a solution of sodium carbonate. The upper portion of this outer case is supplied with compressed air, which, according to the rate with which it is allowed to pass into the outer chamber, causes the liquid to rise in the three cylinders, in which are suspended the iron plates. The liquid, as it rises, comes in contact with the various iron plates, one after the other, and more or less resistance is thus cut out of the circuit, depending upon the height of the solution. By releasing the air pressure in the outer compartment, the solution immediately drops into the lower part of the case, and the plates are then entirely separated from each other. The entire height through which the solution rises is less than 12 inches. This resistance box, which is the result of a large amount of experimentation, enables the motor-driving torque to be kept constant during acceleration. The air exhaust valve is a lift type of valve, normally kept open by a spiral spring. The valve for operating the rheostat is compound, haing several ways through it. On being operated it first opens a clear way for the compressed air to a cylinder, and to the top of a piston, which compresses the spiral spring above referred to, and closes the exhaust valve. The air is then admitted slowly through a small throttling aperture, which admits the air at low pressure to the outside of the resistance box casing. When half-speed has been attained, the motion of the controller lever, when thrown to full speed, causes the air-cock to close the throttling aperture and opens another, thus relieving the air above the upper surface of the exhaust-valve piston, permitting the compression spring on this valve to instantly open it, thus throwing in again the whole resistance, almost instantly. These operations are repeated in securing acceleration from half to full-speed, and in securing retardation from full to half-speed, at which time the motors are in "cascade," as described.

The motors are direct-connected to the axle; that is, there is no gearing; the rotor axle is hollow, permitting the car axle to pass through it. The rotor shaft and the car wheels are flexibly connected and thus jarring and vibration are prevented. The rotor has at one end the three collector rings, upon which rest the three carbon block brushes. At the other end of the rotor is a driving flange, which is connected to the driving wheel on that side, through two links, one of which acts by thrust and the other by tension—the two stresses being of equal magnitude.

In the experimental plant at Alte-Ofen, Buda-Pest, a potential of 3000 volts was supplied from a neighboring plant, and the locomotive had but two motors upon it. I am indebted to Director Otto F. Blathy and Mr. Windisch Antal, of Ganz & Company, and to Mr. Francis Jehl, for assistance in preparing this data and for my trips over the road.

THE SIEMENS & HALSKE RAILWAY.

The firms of Siemens & Halske, Allgemeine Elektricitats-Gesellschaft, and Borsig & Company, of Berlin, have formed an organization for the study of problems connected with the operation of electric railways under steam conditions. The work I shall refer to here has been prosecuted by the first-mentioned firm, which has for a considerable period given this subject attention. I am indebted to the company's engineers, particularly to Walter Reichel, the chief engineer of Siemens & Halske, for the data here presented. The Allgemeine Elektricitats-Gesellschaft are also constructing a locomotive for experimental test, and Borsig & Company, the well-known engine builders, are co-operating with the other concerns in this important undertaking. Siemens & Halske had made some interesting experiments with three-phase current in the year 1892 at the "Werner Works," Charlottenburg, upon a truck 360 m long, and in the year 1897 decided to build a special experimental line for testing an electrical equipment employing rotary current motors, and an e. m. f. of 10,000 volts, and for testing various types of trolleys, circuit safeguards, crossing constructions, etc. This line was built from Grosse Lichterfelde to Zeblendorf over the Teltow road, and was undertaken in the spring of 1898, the track for which was laid standard gage, with the power station at about the center of the line. The more recent tests referred to here were conducted in the spring and fall of 1899, and the final tests in the spring of 1900.

The trolley line was originally arranged with the protective net below the conductors, but later an improved method of supporting the trolley wires and protective net was used. In the first arrangement the current was taken off by sliding contacts on the top of the wires, and subsequently by side rubbing or sliding contacts. It was feared that at the high rates of speed desired, the ordinary forms of trolley wheels, loops and rollers, would tend to leave the wire. All three of the trolley wires, which are of hard-drawn copper wire 8 mm in diameter,

were placed at the side of the road in order to get rid of the effect produced upon the telephone system by using the track for one-phase. The wires were held by porcelain bell insulators, tested for one-half hour under water at 1500 volts, and lay at an inclined plane. They were screwed to wooden arms pivoted to the iron poles, permitting the wires to be strung and maintained separately and evenly, both winter and summer. Tension is kept on the wires by heavy weights placed inside the lattice poles at definite intervals which act through a loose pulley and a block with six pulleys, and gives a strain of 1500 kg on the wires; all the supports are lattice poles forty m apart, the ones carrying the weights being heavier and set in cement. As a precaution all the poles are separately connected to the rails by a copper wire 8 mm in diameter. The trolleys consisted of strong aluminum pieces, pivoted about a horizontal axis, and fastened to an iron pipe, the contact parts swinging in a perpendicular p'ane to the working wires, against which they are held by a spring. In the system later employed, all three conductors lie in a vertical plane 1 m apart. Curved iron supports are attached to the lattice poles. At the ends of these supports are tension devices, and the insulator supports are fastened at a slight angle. The three-part porcelain bell insulators are fastened to the support by means of a hempen rope; there is double insulation top and bottom. Sections of the conductor can move sideways, and yield to pressure as in the case of the ordinary under-running trolley. Metallic supports for the trolley wires tightly embrace the neck of the porcelain insulators by means of pressure screws and spring rings. Each is pivoted upon perpendicular axles, all of the same height, which are insulated by strong hard rubber insulators. The loops or bows are of different lengths and inclinations. They also pivot horizontally to pass below crossings, etc., and are controlled simultaneously by a worm gear, operated from inside the cab. The working conductors and trolleys were tested with a current as high as 30,000 volts. Power is supplied from the sub-station of the Grosse Lichterfelde Railway, and has a storage battery and direct-current motors for driving a rotary-current dynamo. The latter is 12-pole, giving normally 700 volts and 50 periods, and 120 amps. to 250 amps. at 500 r. p. m. This machine can be completely altered so that potentials from 385 volts to 4000 volts can be developed. There is also a rotary-current transformer, with a transforming relation of $\frac{750}{10{,}000}$ volts with $\frac{157}{11.5}$ amps. normal. With this plan it was possible to secure 750 volts directly, 2000 volts directly, and 10,000 volts by transformation. The transformer dynamo frame and instrument cases were all grounded as a precaution. As first operated the transformer stepping down from 10,000 volts to 750 volts was drawn along on a separate attached car with trolleys, in order to better observe the sliding contacts, and to be free from the high tension at the motor, which has no iron casing. There was also only enough room in the locomotive for the large resistances and other apparatus. Later an iron top casing was put on the locomotive, in which the transformer was placed. The metal parts of the locomotive are grounded to protect against the difference in potential. The weight of the locomotive, complete, was 16,000 kg, and it is equipped with two rotary-current motors, one on each of the two axles, and operating at 650 volts to 850 volts and 30 horsepower normal. The current is taken direct to the stationary windings. The rotor is provided with slip rings and ventilation. The air gap is 1.5 mm. Tested, these motors show an efficiency of 88.5 per cent, and the highest type of 120 horsepower with 650 volts, which is increased to 200 horsepower at 850 volts. The motors are flexibly suspended, similar to the street railway motors,and can turn upon the axles. Two pair of gear wheels serve to change the speed, with a gear of 1:4.65 for a speed of 40 km, and 1:3.15 for a speed of 60 km. For the operations of 750 volts, 2000 volts and 10,000 volts, the same motors, frames and rotary parts were used—only the stationary parts being exchanged for the direct operation with 2000 volts. A controller constructed for 750 volts is employed for the switching in and out, and for the starting of the motors. The same has in its interor a reverser drum for changing the running direction and a controller drum for switching the stationary windings of the motor in and out. The controller drum is mechanically connected by a chain gear with the starting devices for the rotating parts of the motors. When running with 750 volts, the controller is directly connected with the trolleys. When running with 10,000 volts, it is, however, connected through the transformer, from 10,000 volts to 750 volts, and a switch for 10,000 volts. Running with 2000 volts, the supply conductors to the primary parts of the motor can be cut off from the controller, and the car operated by two auxiliary switches, and without the use of the transformer. The reverser drum of the controller is so arranged that when employing an additional transformer (for instance with 10,000 volts), different currents can be taken off, thus obtaining the higher torque when starting through a higher e. m. f. (850 volts) than during the normal running (650 volts). The reverser drum finally has steps, at which only two phases are connected up, it being thus possible to reduce the running speed by half. The starting devices are completely separated from one another to facilitate the cutting out of each motor, and to avoid any irregularities in the synchronism of the motors, with wheels whose diameters do not correspond. The controller is placed in the center of the locomotive. The high-tension switch is outside at the end where one transformer is placed, and the starting devices are in the corresponding space which the other transformer occupies. The high-tension switch is provided with a tube spark extinguisher, and the controller with a magnetic blow-out and a successive cut-out for the different phases. Connections between the controller, starting resistances and motors are care-

fully insulated to stand 4000 volts, and are mechanically protected by rubber tubes, 6 mm. thick. Connections between trolleys and transformers are protected by one pipe. Ordinary packed resistances are employed, suspended beneath the car floor, near the starting devices, and properly protected. Safety fuses are on each side of the three low-tension circuits, the high-tension circuits being protected at the power house. Siemens horned (non-inductive) lighting arresters are used on the locomotive for each phase. Hand and air brakes are employed, and the usual voltmeters and ammeters. A locomotive with a load of 30 tons was run up to a speed of 63 km in 60 seconds time, with 700 volts and 190 amps. The locomotive alone attained the same speed in 30 seconds. When run with a load of 30 tons at 60 km per hour, the motor consumed 70 amps. at 700 volts. As is known the starting torque varies with the square of the voltage; therefore, by increasing from 670 volts to 950 volts, the starting torque can be increased to double that at the normal tension. This can easily be obtained when employing transformers (in the operation with 10,000 volts) by the addition of coil sections. The speed may he regulated by wheel resistances into the secondary by opening a secondary circuit, or by "cascade" coupling. The first method causes a loss of current; in the second the motor has a somewhat lesser maximum torque — lesser efficiency and a smaller output corresponding to half the number of revolutions; it is, however, preferable to resistance regulation. The same may be said of the "cascade" coupling, in which the torgue is reduced to half of the output—to 1-4. A braking action of the motors was obtained by decreasing the number of alternations of the dynamo through an increase of the field of the driving motors; likewise current was sent back to the accumulator battery, when going down hill.

Steam

STEAM TURBINE APPLICATIONS IN EUROPE.

BY FRANK C. PERKINS.

THE steam turbine is rapidly coming into commercial use for driving machines of various kinds, and has given universal satisfaction where high speeds are at all desirable. The turbine is largely used for operating centrifugal pumps, fans, blowers and many other rapidly revolving machines, such as electrical generators, both of the direct current and alternating current type. The alternator is particularly well adapted to be operated by the steam turbine.

An example of a large electrical plant using alternators driven by steam turbines is that at Elberfeld. An interesting test has been recently made of these steam turbine generators, which is worthy of careful consideration. The steam turbines supplied are of the Parsons' design, while the alternators were built by Brown-Boveri & Co. of Baden, Switzerland. There are two of these direct driven alternators, each operated by a steam turbine having a capacity of 1500 horsepower. One of these units may be seen in the accompanying illustration. The alternator *C*, in figure 2, is a single-phase machine generating a current of a potential of 4000 volts at a frequency of 50 periods per second. The Brown-Boveri alternator, as will be noted in illustration, figure 1, is a four pole machine and supplies the single-phase alternating current at the above frequency at the high speed of 1500 revolutions per minute. The exciter *D* delivering a direct current to the field of the alternator is directly connected to the same alternator and steam turbine shaft. The interlocking valve handles are indicated at *H*, figure 2, and illustrated in figure 1.

FIGURE 1.—1000-KILOWATT ELBERFELD TURBO-ALTERNATOR.

A very complete test was made by Mr. Lindley, Prof. Schroter and Dr. Weber of the polytechnical schools at Munich and Zurich. The steam consumption trials varied from no load to a normal load of 1000 kilowatts and continued up to a maximum of 1200 kilowatts. The maximum steam pressure recorded was 122 pounds, the mean pressure being 95 pounds, and the lowest pressure 68 pounds. Under ordinary working conditions the steam pressure would be much higher and the superheat considerable higher than in the test. The steam pressure had dropped to 7.8 pounds at the end of the high pressure cylinder, indicated at *A*, figure 1. The pressure had fallen in the low pressure cylinder, indicated at *B*, to about 3.4 of a pound at the outlet of the condenser *G*.

The steam consumption at maximum load of nearly 1200 kilowatts, was a trifle over 19 pounds per kilowatt hour. At a load of 500 kilowatts the steam consumption was a trifle over 25 pounds per kilowatt hour, while at about ¼ load the steam consumption was nearly 34 pounds per kilowatt hour. These figures were very close to the guarantees, being considerable under for full load and maximum load. These steam alternators have been in successful operation in parallel with the other generating sets previously installed in the Elberfeld Municipal Electricity Supply Works. These steam generators consist of two 1000 kilowatts, Brown-Boveri alternators directly connected to Sulzer horizontal steam engines, each having a capacity of 1500 horsepower. These alternators are also single-phase machines and supply current for

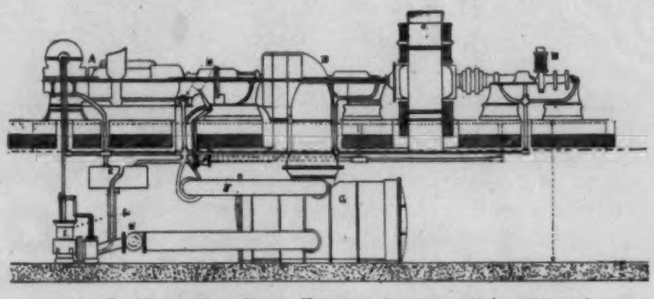
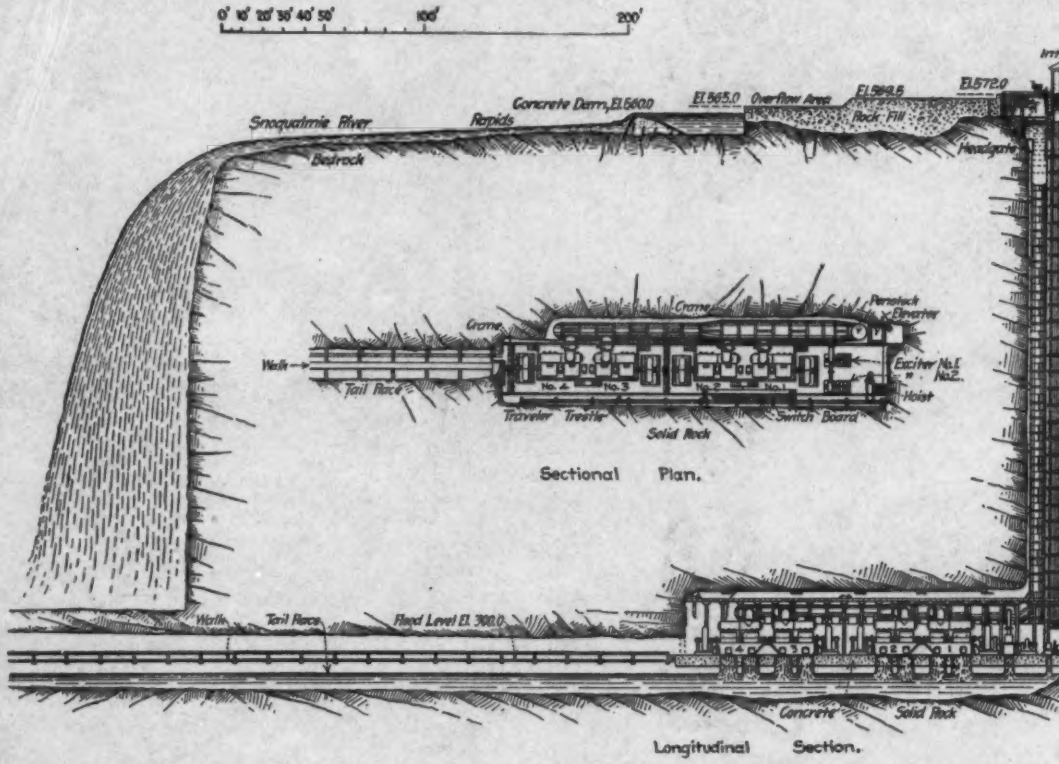


FIGURE 2.—ELBERFELD STEAM TURBINE ALTERNATOR (ELEVATION).

A—High-pressure cylinders.
B—Low-pressure cylinders.
C—Alternator field magnets.
D—Exciter dynamo.
E—Oil tank.
F—Floor line.
G—Condenser.
H—Interlocked valve handles.
I—Air pumps.
J—By-pass from high-pressure cylinder to condenser.
K—Oil pump.
L—Air pump overflow.



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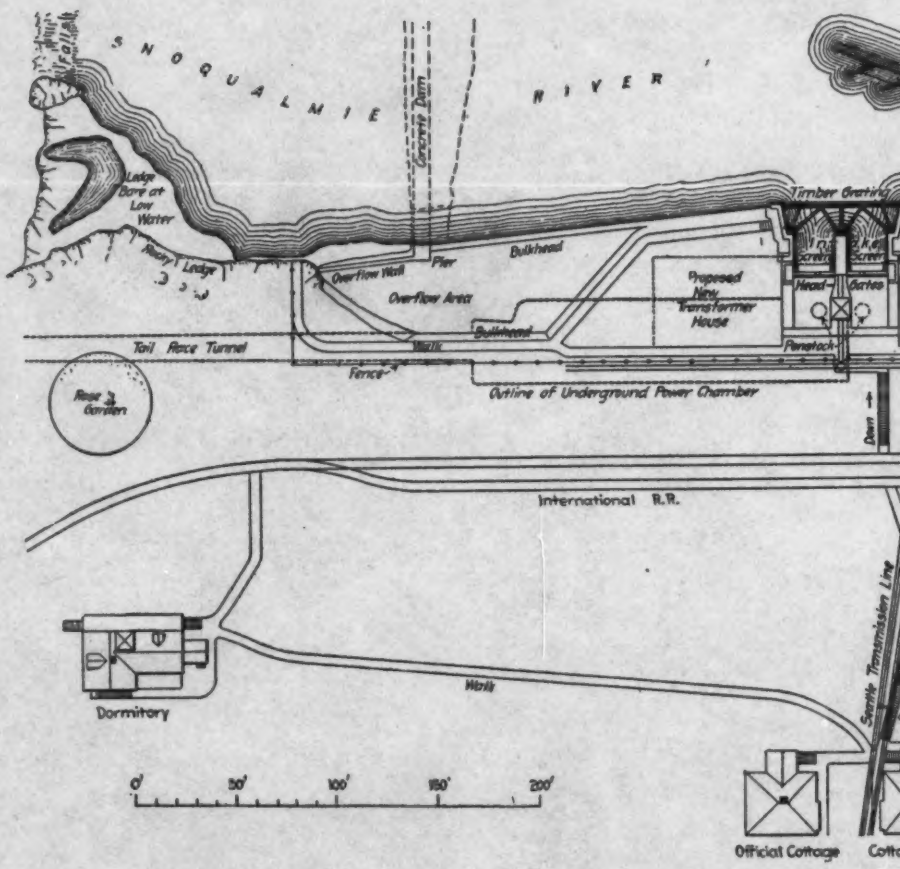
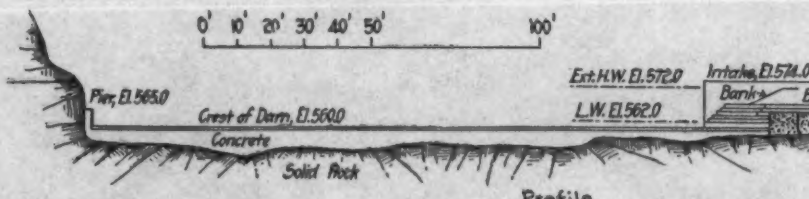


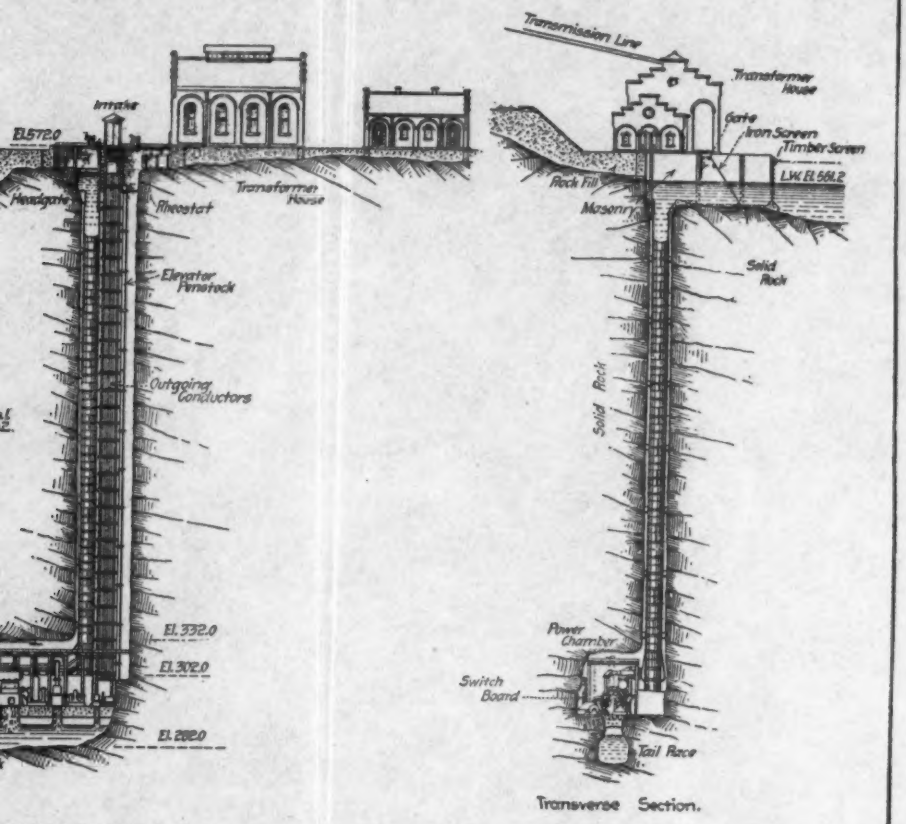
PLAN OF HEAD-WORKS.



SUBMERGED DAM.

WATER POWER PLANT AT SNOQUALMIE FA

Snoqualmie Falls Power C



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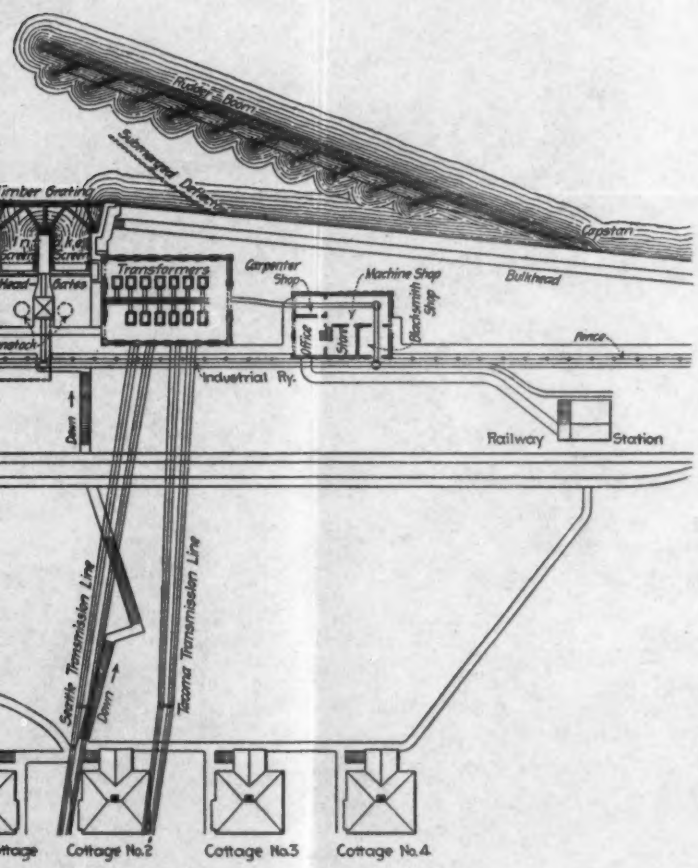

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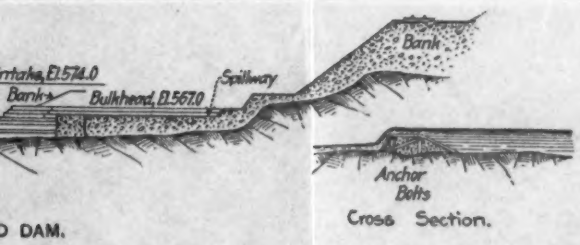
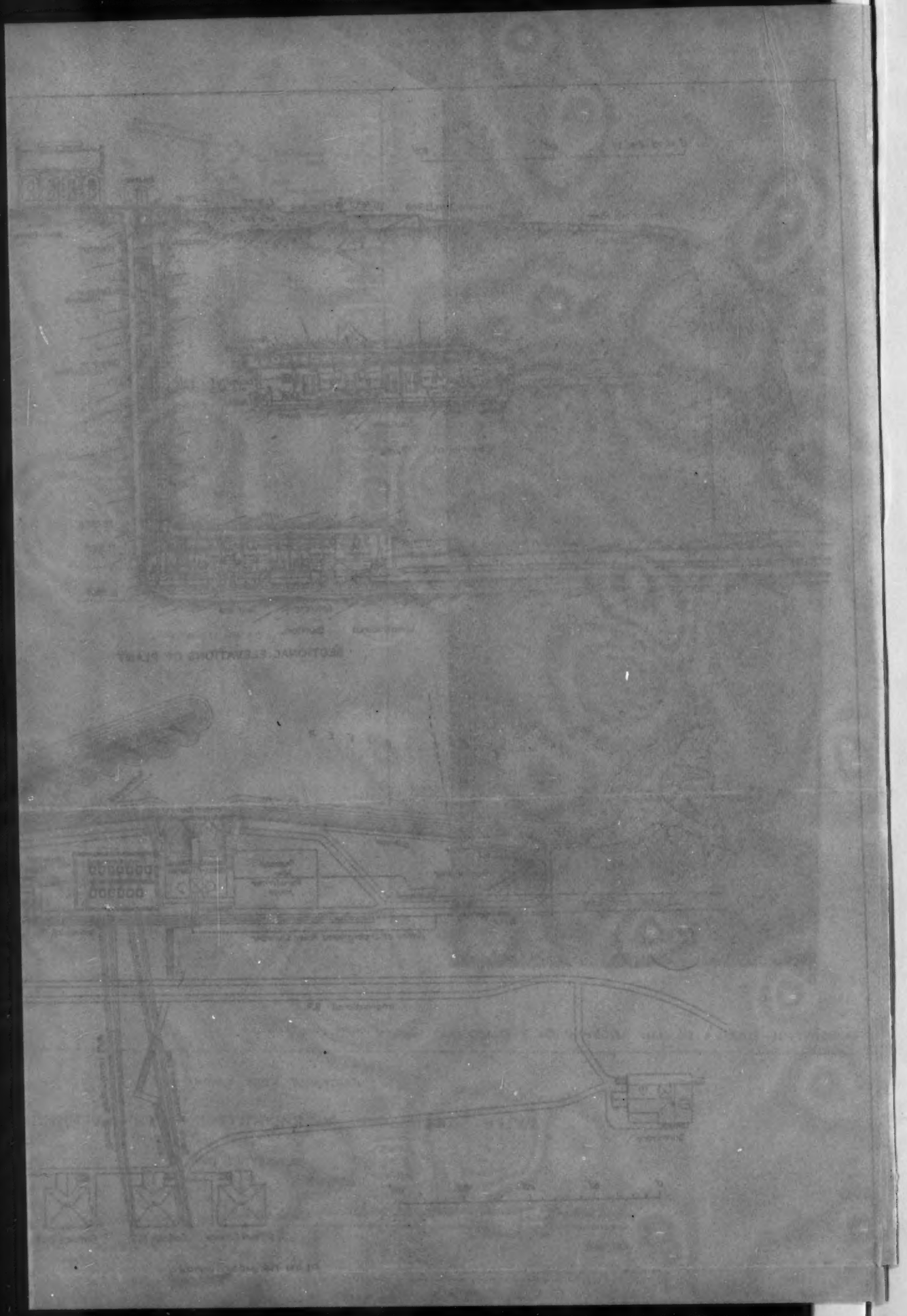


Cross Section.

D DAM.

LMIE FALLS, WASHINGTON.

Power Co.



lighting and power distribution. The variation in speed of the alternators driven by the steam turbines is said to average about 3.5 per cent, both the electrical governor and the centrifugal governor working most satisfactorily. The steam turbine governors were required to hold the speed within .8 per cent under a variation of a quarter of a load. The test showed that the permanent variation in speed varied only from .4 per cent to 1.3 per cent under various changes of loads. The variation in potential of the alternator, it is said, was but a trifle over 1 per cent from no load to full load, the excitation current being constant, and a non-inductive load of water resistance being used. The variation with an inductive load was, of course, very much greater. The iron loss and heating of the armature was somewhat higher than 50 degrees C, the guaranteed rise, although the other parts of the machine was well within this temperature.

The oil pump and oil pump overflow are indicated at and *L*, figure 1, while the air pumps used for the steam turbine are noted at *I*. The oil pumps are connected to an oil tank shown at *E*, below the floor level. The high pressure cylinder has a bye pass connection to the condenser at *J*.

A very interesting exhibit of steam turbines has recently been made at the Paris Exposition by the De Laval Steam Turbine Co. of Stockholm, Sweden. In the foreground, at the left in

FIGURE 3.—DE LAVAL STEAM TURBINE EXHIBIT AT PARIS.

the illustration of this exhibit (figure 3), may be seen a steam turbine dynamo having a capacity of 4600 watts and weighing 7½ cwt. The exterior dimensions are as follows: The total length is 4 feet, 9½ inches; the height, 8 feet, 10 1-2 inches, and width, 1 foot, 4 1-2 inches. The use of the steam turbine is very desirable where only a limited space is at hand for installing the steam plant, such as on shipboard and in office buildings in the center of large cities, where real estate is high. A very high efficiency is also claimed for the turbine, while belt transmission is avoided in many cases, reducing the expense and danger of operation.

In the steam turbine, illustrated at the left, figure 3, the number of revolutions of the turbine and gearing has been determined so as to adapt the machine specially for driving the dynamo directly coupled to the driving shaft of the turbine motor. In view of obtaining at the same time a high electrical efficiency, they have designed special types of dynamos with a higher speed than that generally adopted in common practice for dynamos intended to be driven by belting. The dynamos consequently occupy but little space, and their weight is small in comparison to their capacity. The De Laval magnetic circuit is a closed circuit to avoid magnetic leakage round the dynamo. For the insulation of the commutator mica is used exclusively, and its segments are made of pure hard drawn copper. All bearings are provided with ring lubricators, and the armatures are balanced most accurately, thus tending to prevent vibration during the work.

A De Laval steam turbine blower is also seen in the illustration, which has a capacity of 56,400 cubic feet of air per hour at a water column pressure of 10 inches. The total weight of this machine is only 446 pounds, while the floor space it occupies is only about 4 1-2 feet long by 2 1-2 feet high, with a breadth of 2 feet 5 1-2 inches. In accordance with the results obtained by the direct coupling of the steam turbines to centrifugal pumps, the steam turbine has also turned out very favorably for driving ventilators. In view of the great speed at which ventilators must be run in order to insure high efficiency, belt driving leaves room for much dissatisfaction. Consequently to meet the requirements of the market for a high speed motor in connection with the blower, the direct coupled "steam turbine blowers" and "steam turbine exhausters" have been introduced. Owing to the small standing room required for the steam turbine ventilators, and in view of their small weight, it is said they stand unrivalled for the ventilation of steamships and for supplying forced draught to marine boilers.

There are two separate types of ventilators; one for blowing, called "steam turbine blower," and one for exhausting, called "steam turbine exhauster," the latter being designed for ventilating purposes. With the speed employed, the pressure produced by the steam turbine blowers may be carried sufficiently high for cupola furnaces. The other steam dynamo exhibited has a capacity of 9900 watts, and is one of the oldest outfits placed in service by this company.

A steam turbine pump is also shown which delivers 634,000 gallons of water per hour, against a head of 23 feet. The total weight of the outfit is only 128 1-2 cwt., while the space occupied is only 14 feet by 7 feet, by 4 1-2 feet.

In consequence of their high speed the De Laval steam turbines are peculiarly well-adapted for the direct driving of centrifugal pumps. The pumps have for sometime been in the market, and it is claimed possess several marked advantages over other steam pumps. The special characteristics of the De Laval turbine pumps, viz., their high speed, which is greatly in excess of anything previously known in connection with centrifugal pumps—constitutes a mechanical problem, which has apparently been solved by an improvement in the construction of the wheel and stuffing boxes of the pump, including their lubricating arrangements, and partly by paying the greatest attention to the execution of all the working parts. The high rate of speed has made it possible to reduce the diameter of the pump-wheel and consequently the passive resistance of the pump has been greatly lowered. It was built in 1893, and was sold to the water works at Gothenburg, and was in daily use since that time until placed in the exhibit in February, 1900. None of the original parts have been replaced or repaired. According to estimates made, the turbine shaft has made twenty billion revolutions in that time.

Another interesting exhibit is the apparatus for demonstrating the character of the flexible turbine shaft. It is only by means of making the turbine shaft flexible that the great speed of the turbine wheel has been made possible. Owing to this arrangement all violent vibrations cease as soon as the "critical speed" is surpassed, consequently there is no risk of the bearings running hot, and the machine runs at full speed smoothly and noiselessly. The "critical speed" coincides with the number of vibrations of the shaft, when without rotating, it is made to oscillate freely together with the turbine wheel, influenced only by the weight of the wheel and its own flexibility.

The critical speed of the shaft and the rotator of the apparatus now exhibited, is about 2000 revolutions per minute, which corresponds to 21 revolutions per minute at the handle. Particular attention is called to the sudden diminution of the turning resistance, as soon as the critical speed is surpassed. This

is owing to the cessation of vibrations and the decrease of friction in the bearings.

The principal reason why alternating current was originally preferred to continuous current was that it could easily be transformed, thus reducing to a minimum the cost of wires required for the transmission of power to great distances and for electric lighting of large areas. Later on, however, owing to the simpler construction of the three-phase motors, their uniformity of speed at varying loads, and the entire absence of danger when running in places containing ignitable matter, the alternating current system, and particularly the three-phase system, has come more and more into general use. With the object of supplying the long-felt requirements of an efficient and direct coupled steam driven alternator, the De Laval Company have constructed and put on the market a number of steam turbine alternators for single-phase and for the three-phase currents. In the construction of these machines they have availed themselves of the latest and best improvements, and have succeeded in producing a type which it is said combines the greatest possible simplicity of construction with a high electrical efficiency and affords the possibility of insulating most effectually the windings carrying current of a high tension. Owing to the great speed employed it has been possible to diminish and in some cases to entirely avoid all material in the machine which does not actually serve to generate electricity, thus reducing the weight of the machine to a minimum. All windings are stationary; consequently sliding brushes and contacts are abolished—the only revolving part consisting of a rotator built of sheet iron, pressed on to the shaft.

The generators are provided with an exciter coupled direct to the lengthened shaft of one of the rotators. This arrangement, although frequently employed for such machines, often involves the disadvantage of the exciter turning out rather large and heavy, as its speed is the same as that of the alternator. As a rule the speed of the steam turbine alternator corresponds very nearly with that of a common continuous current dynamo of the capacity required for the exciting current. For this reason the direct coupled exciters are about as large as if they were arranged for belt driving. For the automatic regulating of the tension the exciters are provided with an arrangement which insures a complete compensation not only at varying loads of current but also at a varying lag. In consequence of the small size of the machines, when compared with their capacity, one would suspect that they would be liable to run hot, these alternators, on account of their high electrical efficiency and of their ample and well arranged ventilation operate very cool. All the windings are arranged as interchangeable coils, which can be substituted by reserve coils in case of the insulation being damaged by short circuit, through lightening or any other misfortune. The bearings are provided with ring lubricators. It is claimed that the steam turbine alternator is especially suitable for the following work: Distribution of power in industrial establishments in order to avoid an amount of shafting and transmissions. Thus motive power may easily, and without loss of time, be applied in almost any place. At large building operations, for example: Construction of dams, bridges, factories, etc. Instead of employing a number of portable engines, a generating steam turbine plant for three-phase alternating current is erected, and temporary wires are drawn to places where power is required. The three-phase motors, which undoubtedly are the simplest, lightest and most easily managed motors that can be produced, may be quickly shifted every day from one place to another as the work proceeds. Another advantage may be the employing of steam turbine alternators as reserve machines for electrical plants driven by water power. Electrical power transmissions from waterfalls is nowadays ordinarily effected by means of three-phase alternating current, —which is the most practical system for long distances. If, at the generating station one or more steam turbine alternators are erected, an easily accessible motor power is obtained when the water power runs short. The advantage of steam turbines over piston engine is evident both in view of the smaller standing room required and the facility for keeping the machine clean and in readiness for emergencies.

Professor Carl Hager, C. E., of the Royal Polytechnical College of Stockholm, Sweden, made a trial of a 50-horse-power De Laval Turbine Motor furnished to the Manufacturing Company of Railway Rolling Stock at Sodertelje, and the data may be of interest. He states that in the trial of the 50-horse power De Laval Steam Turbine Motor, it was provided with a Korting's Ejector condenser, and that during the test which was conducted for 8 hours without any interruptions or appreciable variations of load, the motor developed 54.8 brake horse power. The condensing water was pumped through the condenser by a separate small engine. The total consumption of steam was found to be 4,786 kilos, evaporated by 523 kilos of Welsh coal. This gives per hour and horse brake power:

$$\text{Consumption of steam } \frac{4786}{8 \times 54.8} = 10.9 \text{ kilos.}$$

$$\text{Consumption of coal } \frac{523}{8 \times 54.8} = 1.19 \text{ kilos.}$$

In a test of the 50-horse power steam turbine dynamo, by Professor J. E. Cederblom of Stockholm, the following data was obtained:

The test was conducted for 8 hours, from 9.45 a. m. to 5.45 p. m., during which time 617.5 kilos of South Yorkshire coal, and 4,561 kilos of feed-water, at an average temperature of 15.4 Celsius were consumed. The load was determined by lever brakes applied to the armature shafts, which ran at a speed of 1,645 revolutions per minute. The steam was obtained from a tubular boiler with an inside furnace. The boiler pressure amounted to 8.6 kg. pr. sq. cm. above the atmosphere. The motor was placed in the boiler room close to the boiler. In the piping between the boiler and the motor a water separater was inserted. The steam pressure at the turbine was determined by a control-gauge placed between the throttle-valve and the steam-nozzles of the turbine. This steam pressure varied from 8.6 to 7.6 kg. per sq. cm. above atmosphere; these variations were caused by the governor owing to unevenness in the brake load. The pressure in the exhaust pipe of the turbine was, during the whole test constantly — deg. 12 kg. per sq. cm. absolute pressure or equal to a vacuum of 67 cm. mercury-column. The exhaust steam from the turbine was condensed by an Ejector-condenser (Korting's water-jet system), fed with water under pressure from a centrifugal pump driven by another motor obtaining steam from a separate boiler. The temperature of the cooling water was raised by the exhaust steam from 7 degrees to 16 degrees Celsius.

During the test which was conducted, the above stated time without any variations of load worth noting, the turbine developed 63.7 effective horse power. This gives per hour and horse power:

$$\text{Consumption of steam } \frac{4562}{8 \times 63.7} = 8.95 \text{ kilos.}$$

$$\text{Consumption of coal } \frac{617.5}{8 \times 63.7} = 1.21 \text{ kilos.}$$

The information on steam turbines of large size is so meagre, that it may be of interest to note some data obtained by a steam trial of a 150-horse power and a 300-horse power turbine, made by the Mechanical Engineers of the Stockholm Polytechnical College. The steam turbine of 150 effective horse power was built to the order of the firm of W. Ropes & Co., St. Petersburg. The following tests were made under a continuous run of 4 hours duration, with the results here below stated: The load was measured by brake dynamometers, applied to brake pulleys, fitted on the two driving shafts. The dimensions and equilibration of these dynamometers were carefully measured and verified. The steam was generated by a Babcock & Wilcox water-tube boiler, connected to the turbine by an insulated steam pipe about 30 meters in length, fitted with a steam dryer. The steam pressure on the turbine was read on two control

steam gauges fitted to the steam pipe between the governor valve and the steam nozzles of the turbine. The vacuum was read on a column of mercury. The number of revolutions 1054 as a minimum, and 1062 as a maximum, were counted by means of a counter, fitted on the center of one of the driving shafts. The uniformity of speed during each observation was checked by means of a tachometer. The steam consumption was measured by means of a steam nozzle identical with the nozzles fitted in the turbine, through which steam was let out at a constant pressure of 8 kg., and during a time of 10 minutes into a barrel of cold water, of which the weights and temperature were carefully noted before and after the admission of the steam. The weights of the condensed steam at two separate trials did not differ more than 1-3 per cent from each other. The above-mentioned nozzle as well as all the nozzles of the turbine itself were accurately measured in order to ascertain the sectional area of their orifices. The moisture of the steam was also measured and found to be 1.8 per cent as a maximum. Condensation was effected by means of a Korting water-jet condenser, to which the water was supplied by a separate steam turbine pump. This pump was stated by the representative of the works to consume about 7½ horse power as a maximum, but this power was not measured or checked on the occasion. The trial was carried out in six different series of observations, viz.—under full load with 7 nozzles, all designed for condensation, and under successive shutting off of 1, 2, 3, 4, and 5 of these nozzles, so that during the last test the turbine was working with only 2 nozzles. The observations in each series were taken every five minutes; 5 observations during the four first series of tests, and 3 observations during the two last series, and the mean results were as follows:

(The barometrical pressure on the occasion was 743 mm.).

Number of Trial.	Number of open Steam Nozzles.	Number of rev. per minute.	Steam Pressure in kg. per sq cm.	Vacuum in mm. Mercury.	Brake Horse-power.	Steam C'ns'mpt'n per B. HP. per hour.
(As a medium of five observations)						
1	7	1057.2	8.00	670	165.3	7.87 kg.
2	6	1054.4	8.22	658	140.3	8.16 kg.
3	5	1057.0	8.00	666	116.1	8.01 kg.
4	4	1058.8	8.04	674	89.5	8.36 kg.
(As a medium of three observations.)						
5	3	1060 7	7.90	685	65.0	8.49 kg.
6	2	1037.0	8.17	652	38.0	9.98 kg.

As may be noticed, the steam consumption per brake horse power increases gradually as the load decreases. This naturally depends on the greater relative influence of the frictional resistances of the engine when working at reduced loads.

A series of tests with a De Laval Steam Turbine Motor of 300 effective horse power gave the following results: A 300 effective horse power Steam Turbine arranged for rope driving and provided with an Ejector-condenser was delivered by the "Aktiebolaget De Lavals Angturbin" in Stockholm to the "Actien-Gesellschaft der Pabianicer Baumwoll-Manufacturen Krusche & Ender" in Pabianice (Poland), and immediately after the machine had been erected at the factory of Messrs. Krusche & Ender, it was on December 20th, 1899, subjected to a series of trials, with the results summed up here below:

The load on the steam turbine was measured by Prony's brake dynamometers applied one to each of the two driving shafts of the machine. The dynamometers were accurately balanced before the test, and the length of the levers was found to be 2000 meters. The steam-tubing was furnished with 9 steam-inlet nozzles, of which, however, only seven were open at the highest load. The test was executed at seven different loads obtained by opening respectively 1, 2, 3, 4, 5, 6, 7, steam nozzles. Saturated and super-heated steam were both employed in this test.

Observations were taken of the admission steam-pressure required in front of the steam-nozzles, and the temperature of the steam at the inlet valve of the turbine, the vacuum in the exhaust pipe of the turbine box, the load on the brakes, the number of revolutions of the driving shafts, etc. Further, the number of steam-nozzles employed for each load was noted, and the size of their orifices letting through the steam were accurately measured. These were found to be practically all of the same size, the diameter varying only from 6.90 to 7.05 mm.

The steam-consumption was measured by means of a steam-nozzle of the same construction as those fixed in the turbine box, and the orifice of which had a diameter of 7.0 mm. From the steam admission pipe of the turbine a branch-pipe was led to the above named nozzle, and the steam blown through the nozzle could be alternately led into the atmosphere and into a cold water tank standing on a balance, so that the weight of the steam escaping through the nozzle could be accurately measured. The steam pressure in front of the nozzle was adjusted to the same height as the admission pressure at the steam turbine, and the steam was allowed to escape into the water tank during 6 minutes. Observations were taken with both saturated and superheated steam, and also at different back pressures. The result obtained was that the alteration of the back pressure had no perceivable influence on the quantity of steam passing through the nozzle, but with saturated steam the weight of escaping steam was found to be somewhat greater than with superheated.

RESULTS.

Steam admission pressure in front of jet nozzles in kilos per sq. cm.	Temperature of steam at the admission valve—Celsius.	Vacuum at exhaust of turbine in mm. of mercury.	Number of jet nozzles open.	Number of revolutions per minute of the driving shafts.	Brake horsepower	Steam consumption per hour and brake horse-power.
13.55	234.3°	693	7	772	307.8	6.33 kg.
13.8	225.0°	702	6	762	259.0	6.56 kg.
13.8	227.0°	700	5	767	219.9	6.44 kg.
13.8	225.0°	702	4	775	175.0	6.48 kg.
13.4	219.0°	707	3	777	123.3	6.68 kg.
13.8	199.0°	713	2	775	75.2	7 72 kg.
15.0	198.0°	725	1	773	31.9	9.66 kg.

The boiler pressure averaged 15 atmospheres.

The temperature of the steam on leaving the boiler was 390 degrees Celsius during the first test.

The length of the steam piping from the supply valve on the boiler to the admission valve of the turbine, 97.1 meters.

Barometrical pressure in the engine room, 785 mm.

The whole load—307.8 horse power—was thrown off suddenly by loosening the two brakes simultaneously; the following observations were then taken of the behavior of the machine. The index of the Tachometer rose from 750 to 780, indicating an increase of speed of 4 per cent. The vacuum at the turbine-exhaust fell from 700 mm. to 615 mm., i. e. 12 per cent. The steam admission-pressure in front of the jet-nozzles fell from 13.5 mm. to 6.0 mm., i. e., 55½ per cent.

The steam turbine is surely coming to the front for certain classes of work as will be noted from the fact that on December 31, 1899, more than 2000 of this type of turbines with an output of 60,000 horse power, while during 1899 turbines of more than 14,000 effective horse power were installed in various parts of the country.

THE JOURNAL OF
ELECTRICITY, POWER AND GAS

Devoted to the Conversion, Transmission, and Distribution of Energy.

Conducted by GEO. P. LOW.

Official Organ of the Pacific Coast Electric Transmission Association.

Yearly subscription: Domestic, $1.00: Foreign, $1.50, postage paid.
The price of single copies is variable.

Entered as second-class matter at the San Francisco Post Office, August 15, 1899.
Entered as *The Electrical Journal*, July, 1895. Entry changed to *The Journal of Electricity*, September, 1895.

Published monthly at 320 California Street, San Francisco, Cal.
Address remittances and communications to
315 CHERRY STREET, [Telephone, "Pine 76"] SAN FRANCISCO, CAL.

VOLUME XI MARCH, 1901 NUMBER 3

EDITORIAL.

FOUR FACTORS IN CLIMATOLOGY.

It would be too much to say that the lay press stands well in the estimation of the engineering or scientific world as an authority on technical matters. To the contrary it is more frequently a fit subject for ridicule in this direction than otherwise. Occasionally, however, it gets in the right groove, for the time being, and brings out something worthy of serious consideration by all. Such an instance is found in the recent publication of an article by Mr. Alexander G. McAdie, local forecast official of the United States weather bureau, which has a distinct, though by no means emphasized, bearing on the sources of water supply whence are operated the electric transmissions that have made the Pacific Coast famous in electrical engineering circles. Unfortunately Mr. McAdie's observations are more closely confined to San Francisco and vicinity than to the entire West, but even so the moral of his opinions is none the less potent—in fact the wisdom of Mr. McAdie's writings is the wisdom of pure science of the highest plane, and as such it is most wholesome.

"But few of us on the Pacific Coast," says Mr. McAdie, have ever been to Athens. But many of us have been upon the Sausalito hills and either upon the summit of Mount Tamalpais or along the ridges which stretch toward Bolinas. On a memorable day twenty-four centuries ago a Persian monarch sitting on Mount Aegalus looked down upon the fleets off Salamis. That day the East and West met. Professor D. Eginitis, director of the Royal Obseratory at Athens, a skilful meteorologist, has studied the instrumental records of the past forty years and the references in classic literature to the climatic conditions prevailing in Greece 2000 years ago. He finds that there has been no material change in the climate of Greece since the days when Salamis was fought. Sitting on Mount Tamalpais and looking down upon the Golden Gate through which now and then a transport bearing armed men hurries seaward, one realizes that history is repeating itself and that the West and the East have again joined issue, and that the fight is on for supremacy between the old and the new civilizations. We have no classical literature to appeal to in order to determine whether or not our climate has changed since Salamis was fought. There are perhaps redwood trees within view from Mount Tamalpais that were vigorous standards when the great sea fight occurred. Some sylviculturist may yet decipher in the growth of these redwood trees the summed-up history of the sunshine and rainfall of the seasons that seem so far away in the past. And in all probability we shall learn that our climate has not materially changed and that the race of men inhabiting these shores seventy generations ago doubtless experienced the same climatic conditions which we live under to-day. The fogs, the summer afternoon winds, the winter rains and the long dry summers are not then in any sense new conditions. Our written records of San Francisco climatology, thanks to Thomas Tennent, date dack to October 1, 1849. There are not many places in the United States where a continuous record of rainfall for fifty-two years can be referred to."

Continuing, Mr. McAdie reminds one that as there is no royal road to wisdom, so there is no short cut in forecasting. An inspection of the table for the last fifty years will show that there is no regular periodicity in the distribution of rainfall of such a character that it can be used to advantage in forecasting wet and dry seasons. Two extremely wet seasons have been followed by dry seasons, but there are also wet seasons followed by wet seasons. It is apparent that in the fifty years' record wet and dry seasons come and go and that as a rule a dry period seldom exceeds three years. Many of us will not forget in a hurry the dry period from 1897 to 1900. To any one who visited the southern portion of the State in the month of October, 1900, the intense interest exhibited by all classes in the question whether the season was to resemble the three preceding seasons or not, was calculated to make a deep impression. It happened that the forecast official visited the southern section of California in October last, and at nearly every point he was asked to express an opinion in this matter. Notwithstanding his earnest protestations that no seasonal forecast can in the present state of knowledge be made with any certainty, he was reported in prominent headlines in many of the leading journals to have prophesied a wet winter. What he really did say (and this was nearly always correctly reported in the body of the interview) was that a longer continuance of the dry spell was unlikely, and that from the mean path of the storms thus far observed, and the absence of the pronounced features of the continental high area, conditions were more favorable for a return to normal conditions.

The four chief factors controlling climatic conditions hereabouts are, first, the great general pressure area

movements; second, the prevailing westerly drift of the atmosphere in temperate latitudes; third, our proximity to the large mass of water, the Pacific Ocean; fourth, the topography of the coast. Under the first heading we include the general question of storm movement. There is one pleasing tradition concerning our climate which shou'd have received a decent burial with the end of the century, though it is hard to keep such myths under ground. The Kuro Siwo, or Japan current, can, from the very nature of things, play but a small part in influencing the climate of the Pacific Coast. We were all of us in our youth brought up to believe that the mild climate of the British islands was due to the Gulf stream. It is not, but rather to the general eastward drift of the air. Modern science has succeeded at last in making plain the mistakes of the work of fifty years ago. And as for the Japan current, it may be frankly said that the data concerning this stream are so meager that as yet no thorough'y scientific statement concerning its dimensions, extent and probable functions has appeared. We will at once be asked to explain why the Atlantic Coast states and the Asiatic provinces have climates so much colder than simi'ar latitudes in Europe and along the Pacific Coast. As Harvey M. Watts succinctly puts it, "Reverse the aerial current around the world and Japan by the mitigating influences of the Pacific Ocean would have an enternal spring for its climate, while the Atlantic Coast States from North Carolina to Newfoundland would have the mildness of Bermuda, not, however, on account of any one ocean current that laved their shores, but because the conserved warmth of the ocean as a who'e was theirs."

Passing from this very general review of the controlling factors of rainfall at San Francisco, we are interested perhaps more in the remarkable exhibition of fog phenomena in the vicinity of San Francisco than in any other climatic feature. There are those who consider fog an unmitigated nuisance, and there are others who are so enthusiastic as to maintain that San Francisco possesses untold blessings in her wonderous fog blankets. No single article can begin to do justice to the fogs of the bay district. It may be of some interest to compute roughly the weight of water vapor in an average summer afternoon fog lying without the Heads. With a dew point temperature of 10.6 degrees centigrade (51 degrees Fahrenheit) over an area of 100 square miles we wou'd have a gross weight of something like a million tons of water, or the equivalent of a rainfall of .14 of an inch. In some recent scientific papers which have been published in the Monthly Weather Review there is given in detail a discussion of the various conditions controlling fog formation.

The temperatures of San Francisco are remarkably even, the range being very small. Ask a native of San Francisco what is the coldest month of the year and he can hardly tell you. Likewise he is at a loss to name the warmest month. The highest temperature ever recorded at San Francisco was 100 degrees and the lowest 29 degrees. Snow is rare in San Francisco, and since March 1, 1871, there have been but ten days on which snow fell. Thunder-storms are by no means unknown; but the damage done by all the storms of the past thirty years probably does not exceed the damage done by earthquakes during the same period. In both cases the loss has been exceedingly small considering the nature of the phenomena.

THE BERLINER PATENT INVALID.

Judge Arthur L. Brown, of the United States Circuit Court for the District of Massachusetts, rendered a decision* on February 27th, declaring that United States letters patent No. 463,569, dated November 17, 1891, and granted to Emile Berliner for, as the American Bell Telephone Company claimed, "a combined telegraph and telephone covering all forms of microphone transmitters and contact telephones," is invalid, and dismissing the complaint of infringement brought by the American Bell Telephone Company, as plaintiff, against the National Telephone Manufacturing Company of Boston, as defendants. The decision, which is of exemplary clearness and conciseness, decrees the patent to be invalid; (1) because, at the date of the application, June 4, 1877, Berliner had not made the invention covered by the patent issued to the American Bell Telephone Company on November 17, 1891; (2) because the invention described in the patent is radically different from the invention described in the application; (3) because the invention was previously patented by Bell, and because Edison was the prior inventor.

This long-expected decision recalls a story which appeared in these columns some three years or more ago,† and, in fact, it gives the story new zest. It discussed "That Bludgeonless Bogy," and will bear repetition.

Tradition, they say, hands down a fable of a visitor to a lunatic asylum who, after inspecting the various wards, entered the men's recreation grounds, where several hundred inmates were amusing themselves in athletic exercises, or basking on the lawn, or otherwise finding enjoyment, each according to his inclination. The visitor was particularly impressed with a certain great stalwart lunatic whose muscles were as the gnarled oak, whose sharp eyes pierced javelin glances and whose presence was terrifying in its might. His physique was indeed a magnificent habitation for a demented brain, and the visitor in admiring the one, sorely pitied the other.

But the tiger-like keenness with which this lunatic watched every movement of the newcomer was from the outset most disquieting to the latter. His every action was noted and aped; he walked and the lunatic walked; he quickened his pace and the lunatic did likewise; he stopped and the lunatic stopped too, always eyeing the visitor with the wild, fierce, yet cunning and hypnotic look so peculiar to madmen. The visitor was soon terrified at the thought that he might be in a lunatic's power, and determining to leave the grounds, he started toward the gate. The lunatic started too; he broke into a run, but the lunatic was at his heels; he dodged hither and thither with constantly increasing speed, but the demented creature shadowed

*Reprinted in full in the *Electrical Review* (N. Y.), Vol. XXXVIII, No. 9, page 282, *et seq.*

†THE JOURNAL, Vol. V, page 99, August, 1897.

every movement until he fled with all the superhuman energy born of abject terror. Wildly on the chase continued until at times he fancied he could feel the hot breath of the mighty madman upon him—more merciful, he thought, would the starving lions of the jungles of India be than this wild human monster. Oh, the acute mental tortures of the hapless victim cannot be described! With failing strength he felt that the chase would soon be over, then heaven only knew what horror would befall him. At last the end is come and, with the blood bounding through his veins, with nerves unstrung and with utter exhaustion and abject terror upon him, the poor hunted innocent could go no further. He reeled in his terrified frenzy while the lunatic bounced to him and striking him on the shoulder, cried out: "Tag, you're it!"

And so it will be with the Berliner bogy—that offspring of the patent office whose questioned legitimacy of birth has been settled, but whose intellectual soundness, so to speak, is so generally impugned. This bogy is of fearful mein, to the uninitiated. It advances, menaces, recedes, then advances and menaces again, threatening the dismemberment of the hoped-for victim, and when at last it may perchance pounce upon the terror stricken, its threatened annihilation will be but a harmless stroke, while its "Tag, you're it!" will tell that it is all but a game and one in which the other fellow has his inning.

Gas

INDUSTRIAL GAS.—XVIII.

BY FRANK H. BATES.

DETERMINATION OF THE CALORIFIC VALUE OF A SOLID FUEL BY THE LEAD REDUCTION METHOD.

THIS means of determining the heating value of fuels has been almost universally condemned, yet owing to its simplicity and convenience over other methods, the writer feels justified in recommending its use when the proportion of hydrogen in a fuel is approximately known, and when exact heating values are not required.

That very satisfactory results may be obtained when the percentage of hydrogen in the fuel being known permits of the use of a proper coefficient in the formula used in the derivation of the heating value, is shown by the tables I and II, taken from a paper presented by C. V. Kerr at the New York meeting, December, 1899, of the American Society of Mechanical Engineers.

Operation. The general application of this method is as follows: Mix one gram, accurately weighed, of the fuel, finely powdered (if wood the use of a rasp will serve to prepare the sample) intimately with 50 grams of litharge. Place the mixture in a close-grained crucible* and cover with 20 grams of litharge.† Place the crucible and its contents protected by the ordinary crucible cover, in an assay furnace (preferably of the muffle type in which the gaseous fumes from the furnace fuel will be prevented from reaching the litharge and introducing error by a reduction of lead), and very gradually bring to a fusing heat (low red). This will require some fifteen minutes. As the heat is first applied the mixture will gradually fuse with evolution of gas, the carbon and hydrogen of the test sample combining with the oxygen of the litharge and forming carbon dioxide and water vapor which pass off in the gaseous state. As soon as the fusion is complete—that is, on the subsidence of the mixture due to the gases being no longer evolved—bring the crucible to a slightly higher temperature and retain there for some ten minutes to thoroughly collect the lead into a single button at the bottom of the crucible. Remove the crucible from the fire with tongs, tapping gently on the bottom to further collect the lead, and pour quickly into an iron mold previously warmed. As soon as cool hammer the lead button into a cube and weigh.

*A clay assay crucible large enough to be not more than half filled by the charge.

†Litharge (Pb. O) should be free from red oxide of lead. White lead is sometimes substituted. Mitchell claims to have obtained uniform results by the use of white lead.

TABLE I.—FROM PAPER BY C. V. KERR.

BITUMINOUS COAL.

No.	Fuel.	Weight of Coal Grams.	Time of Fusion. Min'tes	Weight of Lead Button Grams.	Calorfic Power B. T. U.	Average.
1	Huntington Fancy Lump.....	1.8293	15	55.9698	13,054	
2	" " "	2.0495	15	61.8461	12,855	12,935
3	" " "	2.0338	15	61.6578	12,915	
4	Pittsburg, Kan., Mine Run....	1.182	8	29.994	10,823	
5	" "	1.0525	13	26.781	10,852	10,735
6	" "	1.318	12	33.166	10,732	
7	" "	1.414	13	34.914	10,531	
8	Ft. Smith, Ark., Mine Run ...	1.0019	13	28.4048	11,915	
9	" " ...	1.4385	21	41.0555	11,995	11,969
10	" " ...	1.2005	12	34.1865	11,970	
11	Baldwin, Ark., Lump.	0.8819	12	23.626	11,260	
12	" "	1.0594	13	28.5725	11,335	11,307
13	" "	0.9950	22	26.8144	11,327	
14	Fayetteville, Ark., Lump.	1.2285	15	34.1030	11,870	
15	"	1.4895	15	40.6994	11,485	11,586
16	" "	2.0023	15	57.3645	11,690	
17		1.6335	15	44.680	11,500	
18	Kansas Lump.....	1.127	15	29.4332	11,230	
19	" "	1.015	15	26.9328	11,150	11,220
20	" "	1.019	15	27.1331	11,190	
21	" "	1.1625	15	28.5901	11,310	
22	Huntington, Ark., Slack.....	1.9068	15	52.2333	11,143	
23	" "	2.0335	15	53.5909	11,227	11,160
24	" "	1.8686	15	47.4247	11,812	
25	Indian Territory Mine Run...	1.115	20	22.697	8,682	
26	" " ...	1.162	20	23.230	8,529	8,656
27	" " ...	1.382	20	28.158	8,696	

TABLE II.—FROM PAPER BY C. V. KERR.

COMPARISON OF OXYGEN AND LITHARGE METHODS.

No.	Fuel.	Weight of Fuel Grams.		Heating Power.		Results.		Probable Error. Per Cent.	
		Oxy.	Lith.	Oxy.	Lith.	Oxy.	Lith.	Oxy.	Lith.
1	Carbon from Granulated Sugar.	.....	2.18	Calibration	14,640	Calibration	All		
2		.....	1.822		14,800		14,330	9 Det.	6 Det.
3		.....	1.879		14,550		.....	.....	.....
4		.....	2.767		13,920		1, 2, 3.6	±2.6	±0.76
5	Ash, 44 per cent.	.....	2.919		13,590		14,617	.....	.....
6		.....	1.937		14,480		.....	.....	.....
7	Bituminous Slack from West Virginia.	1.310	3.197	14,720	11,420	.....	.....	.....	.....
8		1.377	2.306	14,090	11,530	.....	.....	.....	.....
9		1.408	3.453	14,520	11,460	14,620	11,470	±1.1	±0.14
10		1.204	3.502	14,320	11,520	.....	.....	.....	.....
11		0.812	2.877	14,460	11,420	.....	.....	.....	.....
12	Anthracite Coal from Lehigh Valley.	1.328	2.4535	12 660	13,560	.....	.....	.....	.....
13		1 372	2 3165	12,370	13,650	.....	.....	.....	.....
14		1.394	2.0000	12,520	13,604	12,760	13,616	±1.7	±0.08
15		1.528	2.0000	12,230	13,622	.....	.....	.....	.....
16		1.262	2.9675	14,000	13,643	.....	.....	.....	.....

Derivation of values. The derivation of heat values by this method has generally been based on Welter's formula, which assumes that the heat of combustion of any substance is proportional to the quantity of oxygen required. The application of this formula to the litharge method is as follows: In the compound litharge we know

that a certain proportion by weight is oxygen, and further, that in the chemical reaction taking place in the crucible the carbon and hydrogen of the fuel sample combine with a certain quantity of oxygen afforded by the litharge, reducing a portion of the latter to the metallic state of lead. Since these combinations always take place in definite proportions, the weight of lead reduced is indicative of the quantity of oxygen seized by the carbon and hydrogen; and since, if as by Welter's formula the calorific value of the fuel is proportional to the quantity of oxygen used, it could be readily determined. Welter's formula does not hold good for different combustibles however, as can be seen from the following equations:

Carbon, in uniting with oxygen, forms when completely oxidized, carbon dioxide, and evolves in the process of combustion some 14544. British thermal units per pound. This reaction is expressed thus:

C	+	O_2	=	CO_2
(Carbon 12 parts by weight.)		(Oxygen $2\times16=32$ parts by weight.)		(Carbon dioxide $12+2\times16=44$ parts by weight.)

Since for 12 parts by weight of carbon 32 parts of oxygen are required, then for 1 part, or say for 1 pound, of carbon there would be required $\frac{32}{12} = 2.66$ pounds of oxygen, the heat evolved being 14,544 British thermal units; and for each pound of oxygen used we would have

$\frac{1}{2.66} = .375$ pounds of carbon burned, and

$\frac{14,544}{2.66} = 5455$. British thermal units evolved.

Consequently, if we consider carbon the only combustible present, we have but to know the weight of oxygen used to determine the quantity of carbon burned and indirectly the quantity of heat evolved.

But hydrogen is also a constituent of fuels and for the latter we have: Hydrogen uniting with oxygen forms water and evolves in the process of combustion some 62,032. British thermal units per pound.

$2H_2$	+	O_2	=	$2H_2O$
(Hydrogen $2\times2=4$ parts by weight.)		(Oxygen $2\times16=32$ parts by weight.)		(Water $2\times2+2\times16=36$ parts by weight.)

Since for 4 parts of hydrogen 32 parts of oxygen are required, then for 1 part or 1 pound of hydrogen there would be required $\frac{32}{4} = 8$ pounds of oxygen, the heat evolved in such a reaction being 62,032 British thermal units, and for each pound of oxygen used we have $\frac{1}{8} = .125$ pounds of hydrogen burned and $\frac{62,032}{8} = 7754$. British thermal units evolved.

Now, by Welter's law the heat evolved per pound of oxygen used should be the same in both cases, or should be for hydrogen as for carbon 5455. British thermal units rather than 7754 British thermal units. It is this marked discrepancy in the law that has largely occasioned the disuse of the reduction method, since unless some correction were made for the proportion of hydrogen present very little credence could be placed on the results.

We can, however, by entirely discarding Welter's law, and basing our calculations directly on the reactions taking place, use this reduction method to very good advantage and with a surety of very uniform results when we know the percentage of hydrogen.* Let us derive, then, a uniform method of procedure:

The action of carbon in reducing litharge to metallic lead is shown by the equation:

2Pb.O	+	C	=	CO_2	+	2Pb.
(Lead oxide, litharge $2\times206.5+2\times16=445$ parts by weight.)		(Carbon 12 parts by weight.)		(Carbon dioxide $12+2\times16=44$ parts by weight)		(Lead $2\times206.5=413$ parts by weight.)

That is, 445 parts, by weight, of litharge combine with 12 parts of carbon, forming 44 parts of carbon dioxide and 413 parts of lead, the litharge losing its oxygen and being reduced to metallic lead, and the carbon being completely oxidized or burned to carbon dioxide.

From the equation it is seen that for 1 part or 1 pound of metallic lead formed there will be $\frac{12}{413} = .02905$ pounds of carbon oxidized, and, since 1 pound of carbon in burning to carbon dioxide evolves as heretofore stated some 14,544. British thermal units, we have $14,544 \times 0.02905 = 422.50$ British thermal units evolved for each pound of metallic lead reduced, considering carbon as the only combustible.

The reaction with hydrogen is:

Pb.O	+	H_2	=	H_2O	+	Pb.
(Lead oxide, litharge $206.5+16=222.5$ parts by weight.)		(Hydrogen 2 parts by weight.)		(Water $2+16=18$ parts by weight.)		(Lead 206.5 parts by weight.)

Thus 222.5 parts by weight of litharge combine with 2 parts of hydrogen, forming 18 parts of water and 206.5 parts of metallic lead, the litharge losing its oxygen in the reduction to metallic lead and the hydrogen being oxidized to water.

From this equation it is seen that for 1 part or 1 pound of metallic lead formed that there will be $\frac{2}{206.5} = 0.00968$ pounds of hydrogen oxidized, evolving $62,032. \times 0.00968 = 600.469$ British thermal units.

We may now make a general formula to facilitate computations:

Let H = the total heat units per pound of fuel;
C = a coefficient whose value is dependent on the percentage of hydrogen in the fuel;
W = the weight in grams of the metallic lead reduced;
W' = the weight in grams of the fuel used in the test.

Then $H = C\frac{W}{W'}$

In order to determine the coefficient C we must know the percentage of hydrogen and this can generally be found in fuel tables for the several classes of fuels.

Assuming, then, a case in which the percentage of hydrogen is 2, we would have for the value of C:

For carbon, $422.50 \times .98 = 414.05$
For hydrogen, $600.469 \times .02 = 12.00938$

and the total or value of C = 426.05938

*The proportion of hydrogen has been determined for nearly all classes of fuels, and since the values remain fairly constant within the range of a class one is not apt to experience difficulty in selecting a value.

This is true since

$\frac{413}{12}$ = pounds of lead formed by 1 pound of carbon;

and $\frac{413}{12} \times .98$ = pounds of lead formed by .98 per cent. of 1 pound of carbon; and

$$\frac{\frac{413}{12} \times .98}{\frac{413}{12}} \times 422.50$$ (heat units for each pound of lead reduced) = $.98 \times 422.50$ as above, and similarly for hydrogen.

Our formula will then be for this percentage of hydrogen:

$$H = 426.05938 \frac{W}{W'}$$

Suppose the hydrogen were 5 per cent., then

$$422.50 \times .95 = 401.375$$
$$600.469 \times .05 = 30.02345$$
$$\text{and C} = 431.39845$$
$$\text{and } H = 431.398 \frac{W}{W'}$$

In these formulæ no account has been taken of the heat evolved by any sulphur, since owing to its generally occurring as FeS_2, which must be disassociated previous to the combustion of the sulphur, the net heat evolved is doubtful. Pure sulphur evolves about 4000 British thermal units. The error due to neglecting sulphur will be slight, though the formula coefficient may be corrected where its percentage is known.

(Continuation in April number.)

GAS ENGINE GUARANTEES.*

BY W. T. MAGRUDER, M. E.

IT would be both useless and presumptuous to more than outline at this time the history of the gas engine (the history of the Gas Engine was summarized in The Journal for September, 1900, Volume X, p. 65) from its original conception in 1680 by the celebrated Huyghens, but for the purpose of this paper it is desirable to divide it into periods. The period from 1680, when Huyghens suggested the use of gun-powder as a fuel, to 1791, when the first patent was taken out in England by John Barber, may be considered as the "period of suggestion as a possibility." The period from 1791 to 1862, when M. Beau de Rocha brought out his four-cycle idea, more commonly but less properly called the Otto Cycle, may be considered as the "period of conception." The period from 1862 to 1876, embracing the labors of such men as Pierre Hugon, Sir Charles W. Siemens, Boulton, Crossley and Dr. Abel Otto, and culminating in the practical and commercial gas engine known since 1876 as "The Otto Silent gas engine," may be considered as the "period of development." The period of the life of the Otto patent in this country and in England may be considered as the "period of youth and adolescence." The period since the expiration of this patent may be considered as the "period of manhood."

All are familiar with the many attempts made in this country and abroad to improve upon or get around the primary Otto patent. These produced many forms of gas engines, whose good features were heralded in the technical newspapers and in catalogs. Few of these, however, survived, and it is stated that even the most famous, the Clerk gas engine, is now no longer built. But two types of engines have survived the periods of infancy and youth, and they are commonly known as the four-cycle and the two-cycle types of hydrocarbon engines. Within the past five or ten years there has been a very marked development and expansion of these youthful principles, and now that the gas engine business has been firmly and fixedly established on sure foundations, with bright prospects for a long continuation of a valuable and useful life, the writer has deemed it advisable to call the attention of this Association to certain youthful features which are still retained, and which, because they are damaging both to the gas engineering profession and to the gas engine business, should be relegated to the past as quickly as possible. It may be said that the catalogs of the older companies no longer show the youthful crudeness found in those descriptive of the gas engine whose father was a steam engine and whose mother was a gas retort. These manufacturers have some years since discovered that if they desire to stay in business permanently the most profitable course for them to pursue is to state hard facts in an honest, straightforward and truthful way. It is not well, at this time, to dwell further on hindrances to the introduction of gas engines into their legitimate place in the power world; illustrations, both laughable and sad, could be given by each one of us. Neither is it desired to discuss so-called commercial guarantees, such as shipping weights, attendance, repairs, time of delivery and the like, but rather to study for a short while engine guarantees which are distinctly of a technical nature, such as power ratings, regulation, cost of running and fuel consumption.

Under the first of these, it may be said that quite a number of gas engine catalogs fail to recognize that there is a decided difference between the nominal, the indicated and the actual horsepowers. A few still guarantee their engines per indicated horsepower. The difference is a marked one, and can very easily be made clear to anyone of ordinary intelligence. By nominal horsepower we simply mean the amount of horsepower which we, in our judgment or lack of judgment, assign to a particular size of engine, irrespective of whether the engine can produce it or not. This title, peculiar to each and every individual builder, is rapidly becoming obsolete, and the sooner it goes the way of other variables representing fixed quantities the better it will be for all persons concerned. By the indicated horsepower, is meant the rate at which the piston, reciprocating in its cylinder, is doing work. As from 10 per cent to 35 per cent of the work so done by the piston is used up in the friction of the engine itself, only the balance, or from 65 per cent to 90 per cent of the total indicated work, reaches the crankshaft and is delivered by the belt pulley, and is the actual horsepower of the engine. As it is a simple and easy matter for a competent engineer to measure the actual horsepower of the engine by means of an absorption dynamometer or brake, and as the purchaser is chiefly concerned with the amount of power which is actually delivered to him by the engine, it seems both reasonable and proper that engines should invariably be sold and guaranteed by the actual horsepower which they will deliver at the belt pulley or crankshaft, irrespective of any other considerations. This should be the case especially in view of the fact that it is practically impossible to measure accurately with the usual gas engine indicator the indicated horsepower of an engine having either a throttling or a hit-and-miss governor and a load which varies. If the load be constant and the engine can be so adjusted that the indicator diagrams obtained are practically of the same area, the difficulty is removed; but with many engines having either hit-and-miss or throttling governors, the variation in the indicator diagrams is such as to preclude an accuracy greater than 90 to 95 per cent.

The indicator is of inestimable value, and in proper and careful hands without doubt tells the truth; but the usual gas engine indicator tells the truth for only the one double revolution for which a diagram is taken, and gives no indication of the amount of work which is being done while the card is being removed

*Abstract of a paper read before the National Association of Gas and Gasoline Engine Manufacturers, February, 1900.

from the paper drum and another one put in its place. The best that we therefore can do is to strike an average of the mean effective pressures of as many indicator diagrams as it is possible to accurately take in a given time, and from this average mean effective pressure determine the average horsepower for the time so taken. If a more accurate method than this is desired, the ordinary indicator must be replaced by what is known as a continuous indicator, which has not as yet been brought to practical success, even in the hands of its inventors, and of course it has not been put upon the market. The chief value of the indicator will be found to be in the indications that it gives of the faulty setting of valves and of excessive back pressures. For example, an indicator applied to an engine which would not give the desired horsepower showed to the engineer in charge the fact that there were obstructions in both the air inlet and the exhaust outlet pipes, and that a large amount of power was therefore being consumed in sucking in the air, and in driving out the burnt gases. Many other uses of the indicator, with which you are all doubtless familiar, could be cited so as to show its great utility, both in the testing room and with the engine on its permanent foundation; but the accurate measurement of power under varying conditions is not, in the opinion of the writer, one of these uses.

One sometimes reads in catalogs that "our engine is the only one on the market that will run an electric light plant successfully." Just what this means and just what the catalog writer's standard of success may be is not stated. In other catalogs are found writers willing to say that the variation at the switchboard with their so-called "electric engine" is but one volt, "the variation in the gas engine being but 1½ per cent." In fact, one maker claims that "their regularity is 1 per cent," while another claims to be able to run his engine at "an absolutely uniform speed, which may be varied instantly from 50 revolutions per minute to 600 revolutions per minute." The fact that many gas engine builders have not yet loosed themselves from the tethering strings of the steam engine is evidenced by the frequent allusions and comparisons to that inefficient but very useful machine. It must be borne in mind, however, that when comparisons are made it is presumptive evidence that the thing compared is admittedly inferior to the thing with which it is compared. It is a fact which numerous tests have proved that there are on the market today steam engines whose guaranteed and obtained regulation is within 1 per cent from no load to full load and back to no load. These engines may be directly connected to the armature shaft of the generator by rigid couplings. To say, therefore, that a gas engine regulates as closely as a steam engine should mean that it regulates to within 1 per cent. There doubtless are some steam engines which do not regulate any more closely than do some gas engines, but the writer has never seen any steam engine which regulated as badly as some gas engines which he has seen. This whole subject of accuracy in regulation is necessitated by the fact that the manufacture of electric lamps has been so perfected that a variation in the regulation of the generation of current means a great decrease in the life of these lamps, and that the purchaser of an engine for generating power with which to generate electricity to be used for incandescent lighting can therefore afford to pay a higher price for the same, in order to get an engine whose failings will not be visited upon the lamps. With extremely heavy fly wheels on not only the engine, but on the jack shaft and also on the armature shaft, regulation can be obtained which doubtless will be within two volts; but the question still arises whether it is advisable to pay in extra journal friction this very high price in order to obtain this increase in regulation. In some cases which have been reported, this extra journal friction has amounted to from 10 to 15 per cent. When a manufacturer finds himself caught in a contract in which he has agreed to furnish power with a definite regulation of speed, there is little left for him to do but to adopt the principle of kinetic energy as worked out in the fly wheel.

The cost of running a hydrocarbon engine is a direct function of the physical properties and cost of the fuel used. When a hydrocarbon engine was of necessity a gas engine using coal gas, there was no indefiniteness in the subject, but when city gas plants replaced their coal gas apparatus by appliances for manufacturing water gas or some other form of enriched vapor, the cost of the gas was decreased and likewise sometimes the cost of running the engine. When it was found that not only so-called gasoline, but kerosene, petroleum oils and petroleum residue could be used in the generation of power by the gasification of one or other of these liquids, the problem of hydrocarbon engine economies took on a much more complex form. It is absolutely essential that the engine manufacturer of today in making guarantees as to the cost of running should not only know the cost per cubic foot per gallon of the fuel which is proposed to be used, but the calorific value of the fuel per cubic foot, per pound or per gallon, under known conditions, and also the other physical properties of the fuel. Employes of the Standard Oil Company have stated to the writer that their company is unwilling to guarantee the so-called 74 degrees B. gasoline, but simply sell it as "stove gasoline," and of a variable specific gravity. According to the strict use of the word, gasoline is a petroleum ether whose specific gravity is between .629 and .667, corresponding to the gravity of from 95 degrees to 80 degrees B., and that the so-called 74 degrees stove gasoline is a petroleum spirit, and is what is known as "c. benzine naptha," having a specific gravity of .686. Gasoline engine manufacturers should, therefore, be extremely careful how they guarantee the cost and the fuel consumption of such a variable and volatile substance as benzine, naphtha, or stove gasoline, and should remember that the gasoline ether has a still lower temperature of evaporation.

The most difficult subject to treat completely and yet in but few words has been reserved for the last, and is the more difficult because the more technical. A fuel is sometimes defined to be that substance which, by combustion with the oxygen of the air, can be used for the economical generation of heat. Under this head, therefore, may be included the various artificial illuminating gases, natural gases, water gases, producer gases and the various liquids obtained either directly or by distillation from petroleum products. As these vary so greatly in their specific gravities, physical characteristics and calorific values, it is manifestly impossible that any engine can be designed which shall be equally efficiently adapted to either illuminating, natural or producer gas without any change whatever. By the calorific value of a fuel is meant the number of British thermal units which a cubic foot or a pound of that fuel, at a known temperature and pressure, will produce when completely burned in an adequate supply of oxygen. Referring to tables as usually found in books, it will be seen, for example, that Pittsburg natural gas has 495 heat units per cubic foot, while natural gas from the Burns well in Butler county, Pennsylvania, has 1,151 heat units per cubic foot; that water producer gas has 104; that American water gas has 85; that 15-candle power illuminating gas has 620; that gasoline vapor has 690 heat units per cubic foot, or 11,900 per pound of gasoline. This being the case, it is evident that a cubic foot of Pittsburg natural gas, having 495 heat units, will not require as much air per cubic foot as a cubic foot of Butler county gas having two and one-third times as many heat units, and in consequence will not give off as much heat or produce as much power; hence it should not be expected that a 10-horsepower engine using Butler county gas will give ten horsepower when using Pittsburg gas. Again, as the heat units in a cubic foot of gasoline vapor and a cubic foot of 16-candle power illuminating gas are said to be practically the same, the power illuminating gas are said to be practically the same, the power obtained from a gasoline engine using the gasoline vapor should be practically the same as the power obtained from a gas engine using the 16-candle power illuminating gas; but it does not necessarily follow that the ratio of air to gas

should be the same, as the chemical constituents of the two fuels are different. Neither does it follow that duplicate engines using these two fuels will give the same amount of horsepower without any change whatsoever.

The practical point, then, for consideration is this: In guaranteeing fuel consumption, not only must it be known what the fuel is that it is proposed to use, but also the calorific value of that fuel and the best proportion of air with which to supply it. As an illustration of this one catalog guarantees to deliver an indicated horsepower on 17 cubic feet of coal gas or 15 cubic feet of natural gas. If the natural gas has 1,000 British thermal units, the coal gas would have to have 882 thermal units, if equally efficiently consumed, to produce the same power. This would mean that it would have to be 24-candle power coal gas; or, if the coal gas had only 700 British thermal units, then a natural gas having 793 would be in the same proportion. Again, as it is essential that there should be fuel in order to generate heat, so is it exactly equally essential that there should be an adequate supply of oxygen, which means air, in order that this heat shall be generated. When we say that we burn 20 cubic feet of gas per horsepower per hour, we might with equal correctness say that we burn 120 cubic feet of air per horsepower per hour, as that is exactly what we do. Hence, as a gas of a high calorific value usually requires more air than does one of low calorific value, it is absolutely essential that the air valves, passages and pipes which supply air to the engine should be of the proper size. This is a point which cannot be emphasized too strongly, for the reason that in the experience of the writer both gas and gasoline engines could be greatly improved by the enlargement of the air inlet. In one case an engine greatly exceeded its guaranteed horsepower when air was fed to it by means of a blower. In another case, it was apparently intended by the builders that the air should be sucked in through a pipe from the base through cracks between the base and the foundation—a manifest absurdity. In another case, a 20-horsepower engine, which gave but 19 horsepower, gave 22 when the air pipe and several elbows were removed so as to allow the air to get to the air inlet valve directly and without excessive friction. This is equally true of the gas supply pipes. It is the writer's practice to advocate pipes at least one size larger than the gas inlet valve, as he finds that more power can be obtained by allowing the engine to take a full supply of gas at as great a pressure as possible whenever its governor so elects, rather than to throttle the pressure and decrease the quantity of gas in a charge. As the volumes of gases increase with temperature and decrease with pressure, the colder the gas and the higher the pressure the less will be the number of cubic feet of gas at that temperature and pressure which will be used per horsepower per hour. In one case a 75-horsepower engine is said to have run for a month, using less than ten cubic feet of natural gas per horsepower per hour. When the writer heard of it, instead of congratulating the owners, he inquired why they had used so much. Upon inquiry it was stated that the average temperature of the gas for the month was about 20 degrees F., and that the average gas pressure was 18 pounds per square inch. If the gas had been supplied at atmospheric pressure or even at one-half pound pressure and at 60 degrees F., there would have been required about 23½ cubic feet of it to weigh as much as 10 cubic feet of the same gas when under 18 pounds pressure and at 20 degrees F.

Another illustration of the application of the same principle under similar but opposite conditions to the above can be cited in the case of an engine using city gas at ten to twenty tenths of water pressure and at 60 degrees F. when in the mains. When the engine is first started, the gas pipe, cock, gas inlet valve, mixing chamber, etc., are comparatively cool; but after an hour's running, especially at full power, they all become warmed up and get quite hot, and as a result the temperature of the gas is increased, we will say to 260 degrees F., for a figure, or an increase of 200 degrees F. while passing from the gas bag to the interior of the cylinder and before the gas inlet valve closes. Now let us consider what this means. The gas was at 60 degrees F., which is 460x60, or 520 degrees above the absolute zero of temperature of the Fahrenheit scale. Now it is at 260 degrees F., or 460x260, or 720 degrees F. on the absolute scale of temperature. As the volumes of gases are directly proportional to their absolute temperatures, one cubic foot of gas at 60 degrees F., or 520 degrees F. absolute, will occupy 1x720-520 or 1 5-13 cubic feet when heated to 260 degrees F., or 720 degrees absolute. Or, to reverse the proposition, as the temperature of the gas is increased 200 degrees F., one cubic foot of cylinder gas volume will be completely filled by 13-18 or .72 cubic feet of gas as measured by the meter. The same proportions and reasonings hold in the case of the air supply. This is one of the reasons why many hydrocarbon engines let down and do not give the same horsepower on the last hour of the test when working at full load that they did on the first hour. The above is but an illustration of the application of Gay-Lussac, or Charles, law of physics to an everyday gas engineering problem.

One more illustration must suffice to illustrate the application of the Boyle, or Mariotte, law of gases to the same problem. Let us assume that we have both gas and air delivered to us at 60 degrees F., so that the question of temperature does not enter, but that, owing to our altitude above the sea, the pressure of the atmosphere is only 10 pounds per square inch, instead of say, 15 pounds. That means that to get oxygen to consume with our fuel, instead of using 6 cubic feet of air per cubic foot of gas, we must supply 6x15-10, or 9 cubic feet, and that means that our air inlet pipes and valves and our cylinder must be just that much larger.

The practical conclusion then from these illustrations is that, for the best results, the gas and air inlet connections and valves should be kept as cool as is practicable and should be properly and correctly proportioned for the fuel and air which they are going to use. Hence, in making engine guarantees as to power ratings and fuel consumption, it is essential that both the pressure of the air and the character and quality of the fuel that is to be used, its calorific value and specific gravity, its pressure and temperature, should be definitely and completely specified.

The writer has suggested the guaranteeing of a horsepower on a given number of heat units with a given fuel. There will then be no guessing, as a horsepower is 33,000 foot pounds of work per minute, and as there are 778 foot pounds in a British thermal unit, it would mean that 33,000x60 divided by 778, or 2,545 B. T. U., would be required per hour for the generation with perfect efficiency of one indicated horsepower. Then, if the thermodynamic efficiency, or its efficiency as a heat engine, was 25 per cent, it would require 10,180 B. T. U. per indicated horsepower, and if the friction, etc., of the engine was 15 per cent, then 11,976 B. T. U. would be required per actual horsepower. This is the practice in many lines of steam and electrical engineering today, and it is suggested as a suitable method of guaranteeing gas engine performances.

The day has gone by in the history of gas engine manufacture when gas engine guarantees can be made and accepted and paid for on "so many feet of gas per horsepower," and nothing more. Gases vary like other natural and manufactured commodities, and, in the opinion of the writer, this National Association of Gas and Gasoline Engine Manufacturers has a great mission of education to perform in making power users understand these things intelligently. It may be death and bankruptcy to the ignoramus and the fraud, but it will be life and income to the intelligent and the honest manufacturer.

TRADE NOTICE.

The Bullock Electric Manufacturing Company has recently opened an office at Buffalo, New York, 675 Ellicott Square. The office will be under the management of Francis B. Smith, an electrical engineer of wide practical experience.

Transmission

SWISS ALTERNATING-CURRENT POWER PLANTS.

BY FRANK C. PERKINS.

SOME of the most interesting polyphase and monophase power transmissions recently installed in Europe have been those of the Oerlikon Electrical Works of Zurich, Switzerland. In the "La Goule installation in the Jura," the monophase system is used with a line potential of 5000 volts. The district supplied is quite extensive and includes a number of places within a radius of about 20 kilometers. The energy

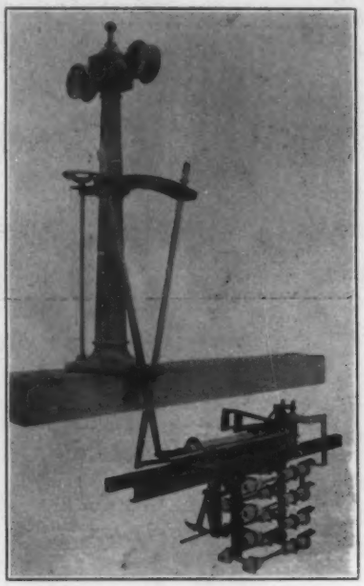


FIGURE 1.—AN OERLIKON SWITCH PILLAR.

is developed by monophase generators, power being supplied from the river Doubs. The accumulator plant of St. Jmier is also connected with the La Goule system, being supplied by a synchronous motor driving two direct current dynamos.

ELECTRIC SUPPLY PLANT.

The three phase municipal installation at Zurich, recently completed by the Oerlikon Company, consists of three polyphase generators directly connected to high power horizontal steam engines. These machines are also designed to supply single phase current when desired. One of the generators has a capacity of 750 horsepower and the other two have each a capacity of 1000 horsepower. The potential used is 2000 volts, and the current is used for light, power and traction purposes. The generators are of the direct connected flywheel tpye, driven by tandem compound engines, and all 2000 volt switches and instruments are controlled or mounted on switch pillars as indicated in figure 1. A sub-station at Selnau, near Zurich, is shown in figure 2. This transforms the polyphase current to direct current for power and traction work. Three polyphase motors are used at this station, each driving a direct current generator of 200 kilowatts and supplying continuous current of a potential of 550 volts. The motors are each of 300 horsepower, and operated at 1950 volts, and 50 cycles.

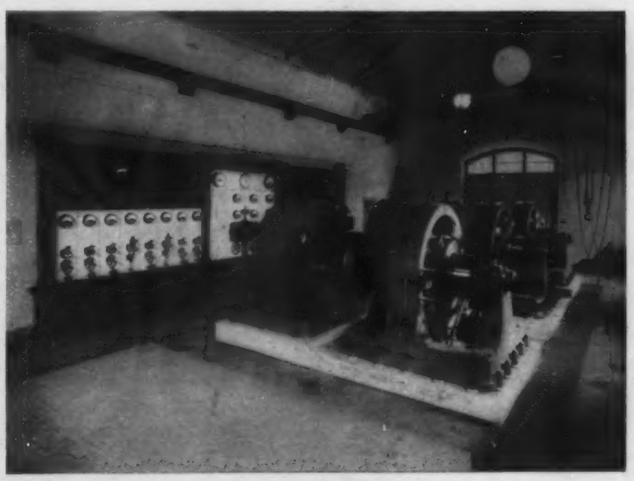


FIGURE 2.—MOTOR-GENERATOR SUBSTATION AT SELNAN, NEAR ZURICH.

In the Oerlikon installation at Les Clees, Yverdon, a water power supplied by the river Orbe amounts to more than 1800 horsepower. This is utilized by six turbines, three of which, as may be seen in figure 3, are directly connected to three polyphase generators, built by the Oerlikon Electrical Works. The turbines have each a capacity of 300 horsepower, and the arrangements of the speed regulators, fly wheels and flexible couplings may be seen in the illustration. The exciters are also shown as directly connected to the shafts of the alternators. The power line extends overland for a distance of 50 kilometers. The primary pressure used is 5200 volts, and the secondary is usually 120 volts.

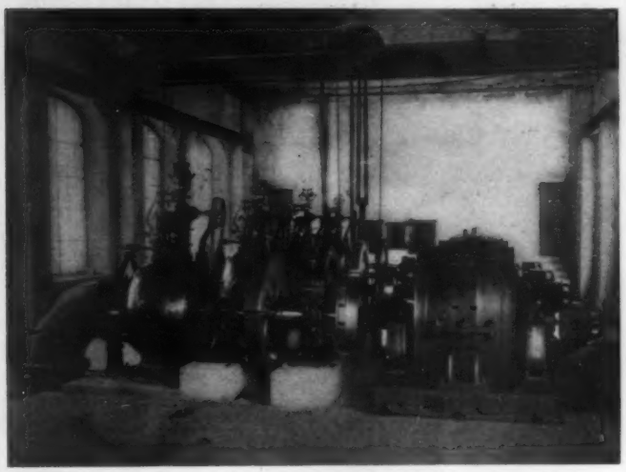


FIGURE 3.—ONE HALF OF THE CLEES-YVERDON POWER HOUSE.

THE DIAMETER OF ROUND POLES.

Roughly speaking, the relation existing between the top and butt diameters of a round pole are to be found in the diameter of the top in inches plus one-tenth of the number expressing its length in feet. Thus, a 35-foot pole measuring 7½ inches in diameter at the top would have an approximate butt diameter of $7\frac{1}{2} + \frac{35}{10} = 11$ inches. Conversely, given the diameter of the butt—11 inches—the diameter of its top in a length of 35 feet would be approximately $11 - \frac{35}{10}$ or 7½ inches.

Chas. H. Baker, President and General Manager of the Snoqualime Falls Power Company, writes: "I have read with great interest the article on the Snoqualime plant in "The Journal," and I desire to congratulate you upon the excellence of the treatment of the subject. * * * Of the several write-ups which have occurred in different magazines or papers concerning this enterprise, yours certainly elucidates the situation more clearly and holds the reader in a manner that none other could possibly do."

Illumination

AN EXAMPLE OF A MODERN ISOLATED PLANT.

A NOTABLE instance of the use of electricity in an isolated plant, applied to both lighting, heating and ventilating systems, is afforded by the new Symphony Hall in Boston, the successor to the Old Music Hall, which for many years has been one of the great musical centers of New England. Symphony Hall is located on the corner of Massachusetts and Huntington avenues and its architectural excellence is locally a matter of almost universal knowledge.

Ground was broken on the site of the new hall in June of 1899, and the dedication ceremonies took place on October, 1900. The general scheme of the interior is on the lines of the Italian renaissance. The walls and ceiling are tinted a light gray, and the upholstery on the floor and in the balconies is done in rich, dark green leather. The proscenium arch is particularly imposing, being 62 feet by 45 feet. The design is a broad band of gold, upon which is a pattern of leaves and fruit.

Incandescent lamps are worked into the design of the arch and groups of them are placed back of it, lighting the stage in such a way that the audience is spared from their direct glare. From the ceiling of the auditorium, which is done in paneling with curved beams, are suspended five artistic chandeliers carrying clusters of incandescent lamps, there being 600 of these in all. Each chandelier is separately counterbalanced by weights hung outside of the auditorium, and may be readily lowered to the floor for examination and renewal. The foyer requires 150 incandescent lamps, and the entire number used throughout the building is 2,000.

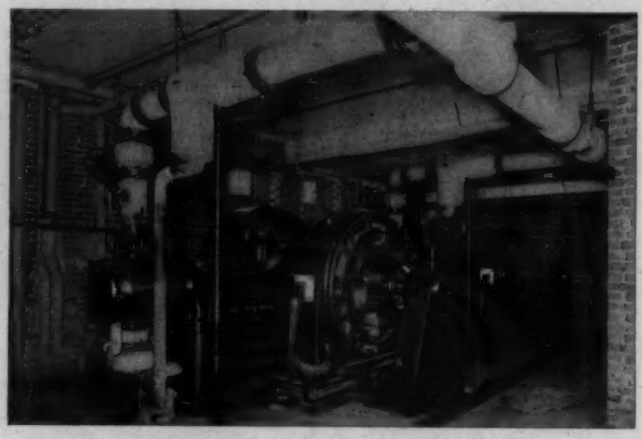
The back of the stage is entirely taken up by a fine organ, into the front of which are several small clusters of incandescent lamps.

The boiler room in the basement contains three Babcock & Wilcox boilers, aggregating 600 horsepower, and working at 80 pounds pressure. The engine room, also in the basement, is equipped with three horizontal non-compound and non-condensing engines, which are directly connected to three Westinghouse direct current generators, of the engine type. Two of these are of 200 Kilowatts capacity each, and the third is of 50 Kilowatts capacity, at 110 volts. Electricity is supplied to incandescent lamps all over the building, and to motors for operating the ventilating apparatus.

The heating and lighting arrangements constitute probably the most nearly perfect system that has yet been worked out.

INTERIOR OF ENGINE ROOM OF BOSTON SYMPHONY HALL, SHOWING WESTINGHOUSE GENERATORS.

Cool air, drawn in from the top of the building through a large shaft, is forced by electrically-driven fans over two coils of piping aggregating 1900 square feet of heating surface. These pipes are supplied with exhaust steam from the engine room, and the temperature of the air may be regulated with great nicety. In hot weather chilled water may be passed through the pipes in place of steam, so that the plant affords both heating and cooling facilities. The warm or chilled air (as the case may be), after passing over these coils is forced by electric circulators through perforations which are cleverly worked into



INTERIOR OF ENGINE ROOM OF BOSTON SYMPHONY HALL, SHOWING WESTINGHOUSE GENERATORS.

the design of the ceiling of the auditorium. The fresh air then circulates throughout the auditorium and goes out through registers placed in the first and second balconies and on the floor of the hall. In this way the entire auditorium is uniformly and thoroughly ventilated and either warmed or cooled. This system of ventilation is operated by five electric motors of 30, 22, 7, 3, and 2 horsepower, respectively.

It should be noted that the ventilating shaft from the roof also serves very conveniently as a conduit for the electric light and power cables, which are grouped on the vertical walls.

Altogether, the new Symphony Hall represents the best contemporary practice in the design of such a building. Its seating capacity is nearly 2,600, the floor seating 1,466 and the first and second balconies about 600 and 500, respectively.

THE HORSEPOWER OF GAS ENGINES.*

COMPUTING the horsepower of a gas, gasoline or oil engine is a process that is practically identical with that of computing the horsepower of a steam engine from its indicator diagram. The mean effective pressure in a gas engine is the difference between the average gage pressure shown by the expansion line and that shown by the compression line, minus the back pressure of charging or suction. Substituting the number of explosions per minute in the gas engine for the number of revolutions per minute in the steam engine, will give a familiar formula for deriving the horsepower of the gas engine. The formula is as follows:

$$\frac{P\ A\ L\ E}{33{,}000} = \text{horsepower.}$$

where P = mean effective pressure;
A = area of the piston in square inches;
L = length of stroke in feet;
E = explosions per minute.

"THE JOURNAL is very interesting," writes S. L. Foster, Chief Electrician of the Market Street Railway Company, San Francisco, in remitting in settlement of five years' subscription.

*From the "Gas Engine Edition" of *The Power Quarterly*, p. 20, Oct. 1900.